DEEP PHARMA INTELLIGENCE

THE YUAN

EVOMICS
Beyond the visible

Artificial Intelligence in Nuclear Medicine

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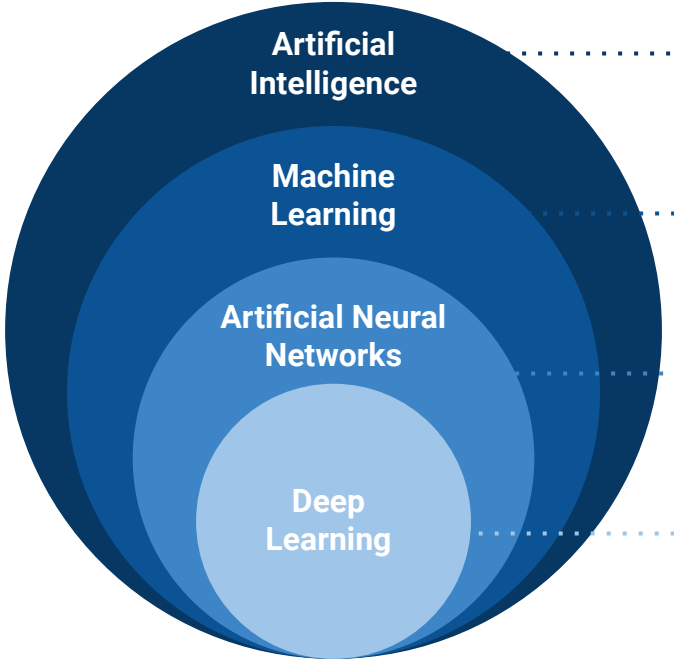
Introduction to Artificial Intelligence



Artificial Intelligence (AI)

Any techniques that enables machines to solve a task in a way humans do

Machine Learning (ML)

Algorithms that allow computers to learn from examples without being explicitly programmed

Artificial Neural Networks (ANN)

Brain-inspired Machine Learning models

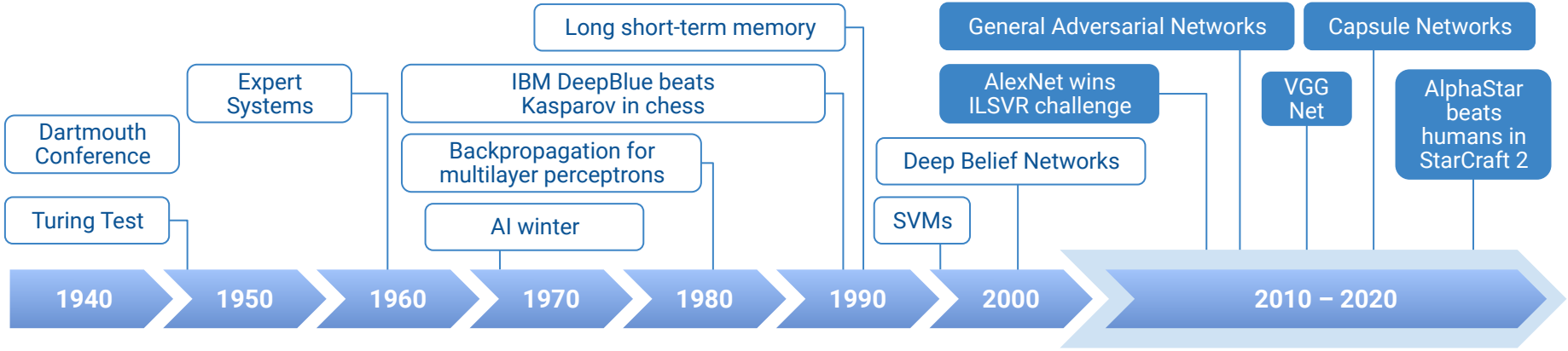
Deep Learning (DL)

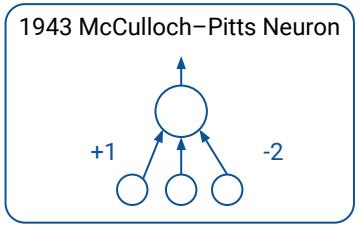
A subset of ML that uses deep artificial neural networks as models and automatically builds a hierarchy of data representations

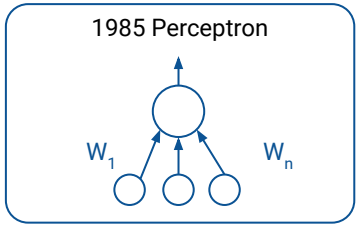
Artificial Intelligence is a collection of computer technologies that enable machines to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages. It allows the machine to sense, comprehend, act, and learn. Artificial Intelligence and Machine Learning make it possible for machines to rationalise, reason, and solve problems. Deep Learning takes machine level to an exponentially higher level of computation through a multilayered neural network.

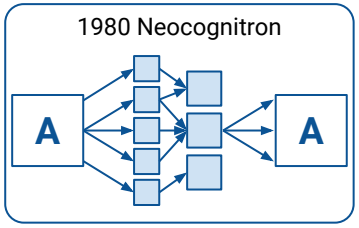
Sources: The Journal of Nuclear Medicine

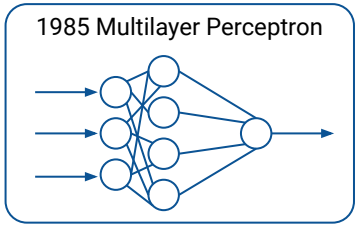
Timeline of AI Development

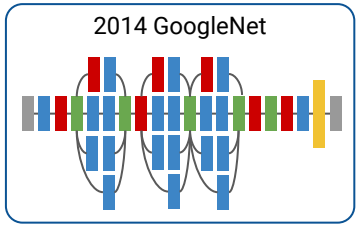


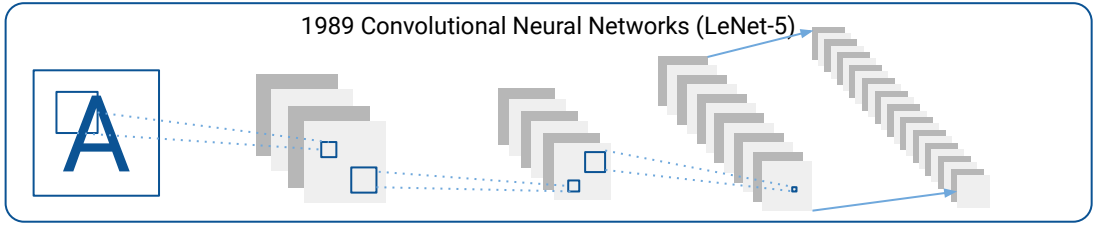


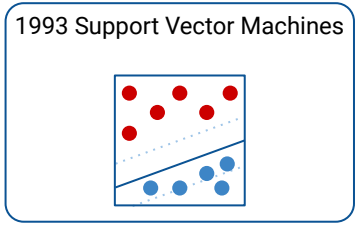


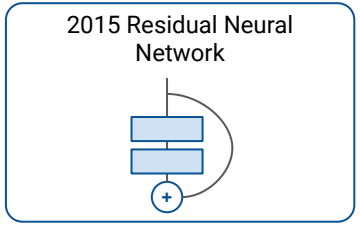












Sources: The Journal of Nuclear Medicine

Introduction to Nuclear Medicine

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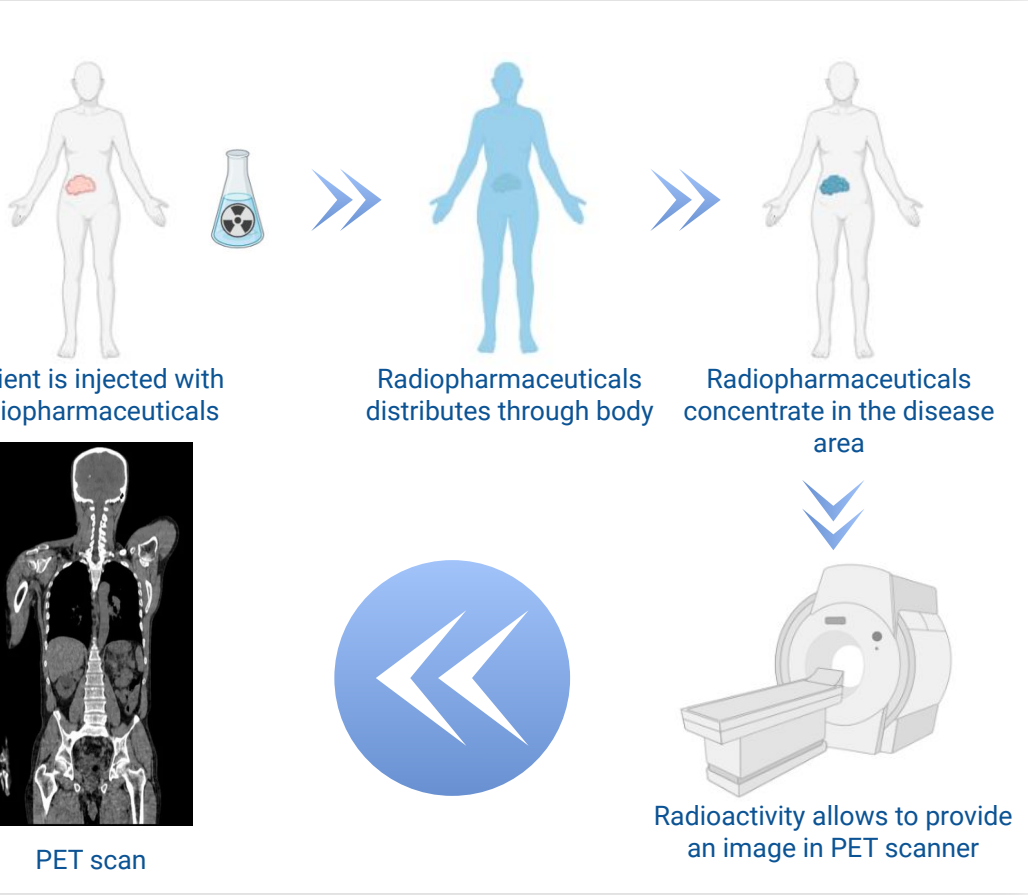
Introduction to Nuclear Medicine: Diagnostics

Nuclear Medicine is a field of medicine that uses radioactive substances which are either injected into or ingested by humans to **diagnose** or **treat a disease**.

For diagnostics, the patient consumes the radioactive substance, which is then distributed through the human body and concentrated in the disease area. The lesion takes it up, and any residue is naturally eliminated. Then the patient is transferred into the scanner, and radioactivity creates an image. An X-ray picture usually gives the first pass, and the second pass gives the PET or SPECT image. The fusion of these images is PET/CT or SPECT/CT images that create a detailed nonmoving image of organs, bones, and tissues in high resolution. Such embodiments allow to clearly see the lesion location and make an accurate diagnosis.

Nuclear medicine imaging is a **combination of many different disciplines**. These include chemistry, physics, mathematics, computer technology, and medicine.

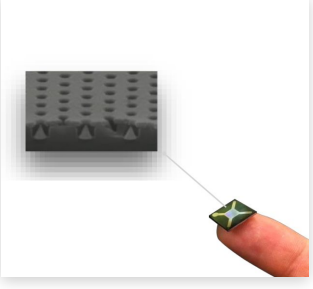


Sources: Nuclear Medicine Europe, Hopkins Medicine

Introduction to Nuclear Medicine: Diagnostics

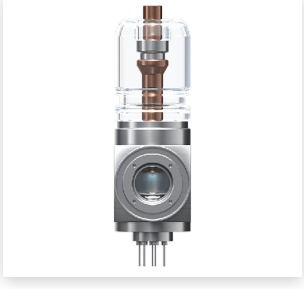
Nanox is an Israeli imaging company whose **AI-based technology** helps **identify** patients at risk of having chronic disease and enable the start of preventative care pathways. Nanox AI solutions were created to fight the most common **chronic and acute diseases** that influence massive populations around the world. Nanox AI's solutions assist physicians in identifying **early indicators of sickness** by utilising medical imagery currently available to the system.

Nanox.SOURCE »



100 Million nano-cones field on a silicon chip emitting digitally controlled electron streams under low voltage

Nanox.TUBE »



Commercially available Digital X-Ray source

Nanox.ARC »

3D computerised tomosynthesis

Nanox.CLOUD

Software platform designed to streamline the radiology diagnostics services and provide billing control

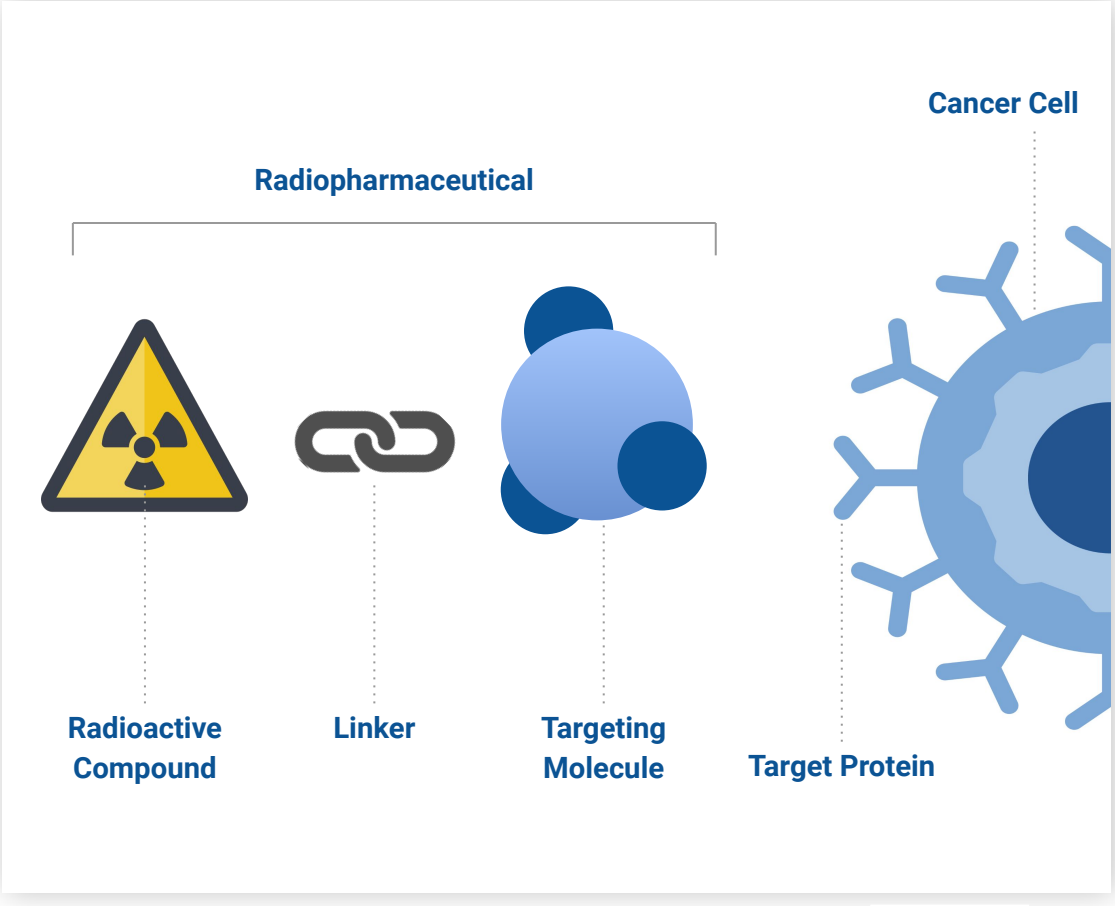
Sources: Nanox AI

Introduction to Nuclear Medicine: Therapy

Nuclear Medicine plays a vital role in the treatment and therapy of the disease.

The **radiopharmaceutical** is injected into the patient for therapy, which then diffuses into the whole body. Then these radioactive substances concentrate in disease cells and tissues as a consequence of the grafting of radioactive atoms (radionuclides) to drugs that have the property to recognise and therefore stay in these specific cells. After the concentration in the disease area, the radiopharmaceutical starts to destroy the disease progressively.

Additionally, nuclear medicine can be implemented in **personalised medicine**. The focus therapeutics areas are neurology, cardiology, oncology, and orthopaedics. The nuclear medicine images help anticipate if the person will respond effectively to the treatment. They allow us to look into the body, make an accurate diagnosis and find the appropriate treatment decision for the patient.



Sources: Nuclear Medicine Europe, Hopkins Medicine

Introduction to Nuclear Medicine: Therapy

THERAPANACEA
Reinventing cancer care through AI

TheraPanacea is a medical technology company, based in France, that uses **AI** to produce cutting-edge software for more efficient and precise **cancer** treatment. **ART-Plan™ –** their intelligent programme for high-precision **radiotherapy**, improves every step of the treatment process flow: from planning to follow-up. **Annotate** by ART-Plan™ is **AI-powered software** that delivers zero-click, automatic delineation of more than 100 organs at risk (OARs) and lymph nodes in a matter of minutes with the same precision as clinical specialists.

GDPR compliant cloud-based online application

3D organ contours for all major cancer sites in a minute

Plug and Play, seamless integration with hospital systems

Reliable and fast delineation of +100 OARs and lymph nodes

Up to 95% reduction of manual tasks involved in the contouring process of OARs

Follows consensus guidelines for standardised and consistent contouring practice

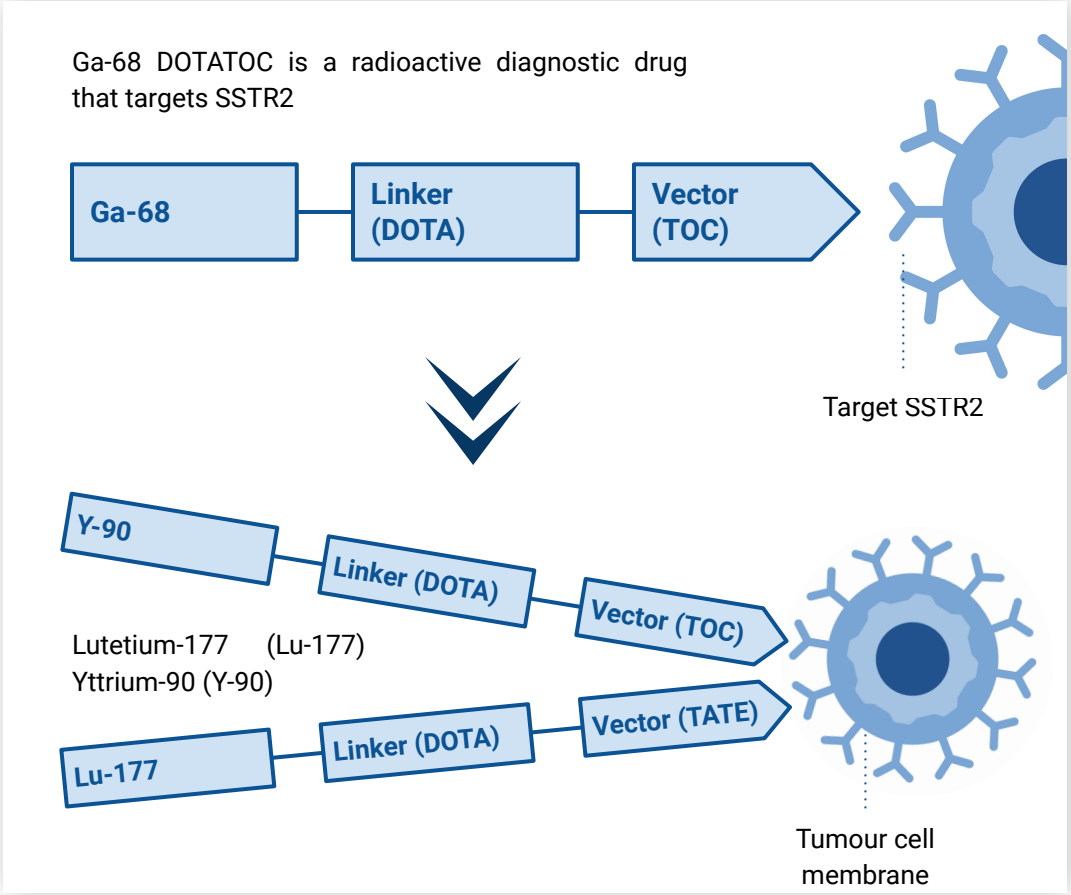
Sources: Therapanecea

Theranostics

Theranostics is a combination of the terms **thera**peutics and diag**nostics**. Theranostics is the term used to describe the combination of using one radioactive drug **to identify** (diagnose) and a second radioactive drug **to deliver therapy** to treat the main tumour and any metastatic tumours. **Theranostics** include **two phases:**

I Diagnostic phase. Certain proteins such as the somatostatin receptor (SSTR2) on the tumour cell membrane that can serve as a target for cancer drugs. If a patient has a neuroendocrine tumour with SSTR2 on the tumour cell membranes, Ga-68 DOTATOC can be injected into and will bind to the SSTR2, and the tumour will light up on a PET scan.

II Therapeutic phase. Once neuroendocrine cancer is diagnosed, Ga-68 can be replaced with another radionuclide that can target and kill tumour cells which have SSTR2 on their membranes. These therapeutic drugs bind to the SSTR2 proteins like a key in a lock, allowing the drug to enter the tumour cells and kill it by damaging that cell's DNA.



Sources: uihc.org

Theranostics

Hermes Medical Solutions is a Swedish medical tech company that was first to develop medical image fusion software which allowed users to view images from many scanners at the same time. This ground-breaking method aids clinicians in localising organ functions by combining **functional** and **morphological data**, thereby increasing molecular imaging and **radiology knowledge**. Their **HERMIA** software provides different levels of analyzing in **oncology, neurology**, **theranostics,** and other fields.

- Support for all camera manufacturers
- Unrivalled vendor-neutral quantitative SUV SPECT® reconstruction
- Simplified workflow and training, standardised across all cameras and hospital sites
- Fast and easy remote access

Complete suite of proven tools for all clinical molecular imaging procedures

- Complete suite of proven tools for all clinical MI procedures
- Designed for speed, refined for quality
- Local and dedicated support with NM trained clinical experts
- Best-in-class dosimetry tools for theranostics

Sources: Hermia Medical Solutions

Nuclear Medicine vs. Radiology

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Radiology vs. Nuclear Medicine

There is a common misconception that **nuclear medicine** and **radiology** are the same. However, despite these fields being close, and in many cases, radiology complements the nuclear medicine approach, there is a **crucial difference between the two**. **Radiology** refers to generating energy that interacts with the body and produces an image using radiology equipment. Radiology professionals then interpret the image to identify abnormalities and diagnose disease. **Nuclear medicine** refers to the usage of nuclear compounds and radioactive materials and then tracking radiation sources in the body to develop a detailed image or video.

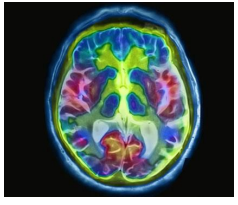
Parameters	Nuclear Medicine	Radiology
Source of Energy	Internal radiation waves coming from the body due to consumed/injected radioactive substance	External energy waves are applied to the body and produced by radiology equipment
Type of Images	Single Photon Emission Computed Tomography (SPECT) scan Skeletal scintigraphy Positron Emission Tomography (PET) scan Combined PET and CT scan Radioimmunotherapy	X-ray Computed axial tomography (CAT) scan Fluoroscopy Magnetic resonance imaging (MRI) Sonogram
Application	Observing of the chemical interactions inside the body and inspect organs and bones	Imaging of the muscles, bones and organs to identify abnormalities and diagnose diseases

Sources: indeed.com

Image Types in Nuclear Medicine

Single Photon Emission Computed Tomography (SPECT) scan

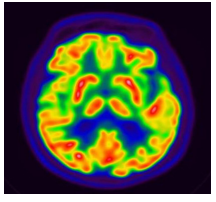
A SPECT scan is a type of nuclear imaging test, which uses a radioactive substance and a special camera to create 3-D pictures.



cognitivefxusa.com

Positron Emission Tomography (PET) scan

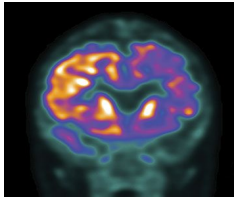
It is a functional imaging technique that uses radiotracers to visualise and measure changes in metabolic processes and other physiological activities.



Radiopedia.org

Combined PET and CT scan

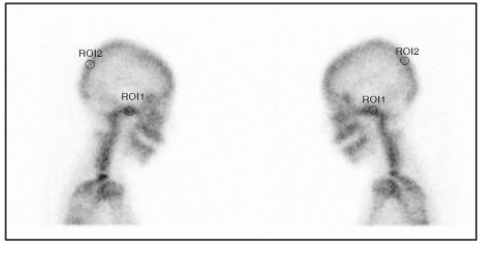
Using a combination of nuclear scanning and x-ray scanning, combined PET and CT machines can reconstruct complex 3-D images.



risimaging.com

Skeletal Scintigraphy

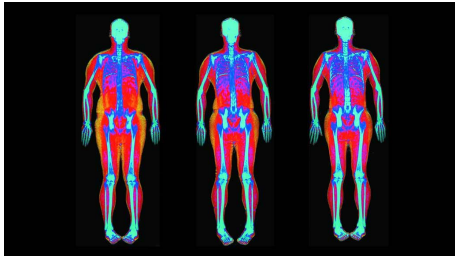
Also known as a nuclear bone scan, this procedure uses a scanner to identify where a radioactive agent collects in the patient's bones.



International Association of Oral and Maxillofacial Surgeons

Dual-Energy X-ray Absorptiometry (DEXA)

DEXA uses a very small dose of ionising radiation to produce pictures of the inside of the body (usually the lower [or lumbar] spine and hips) to measure bone loss.



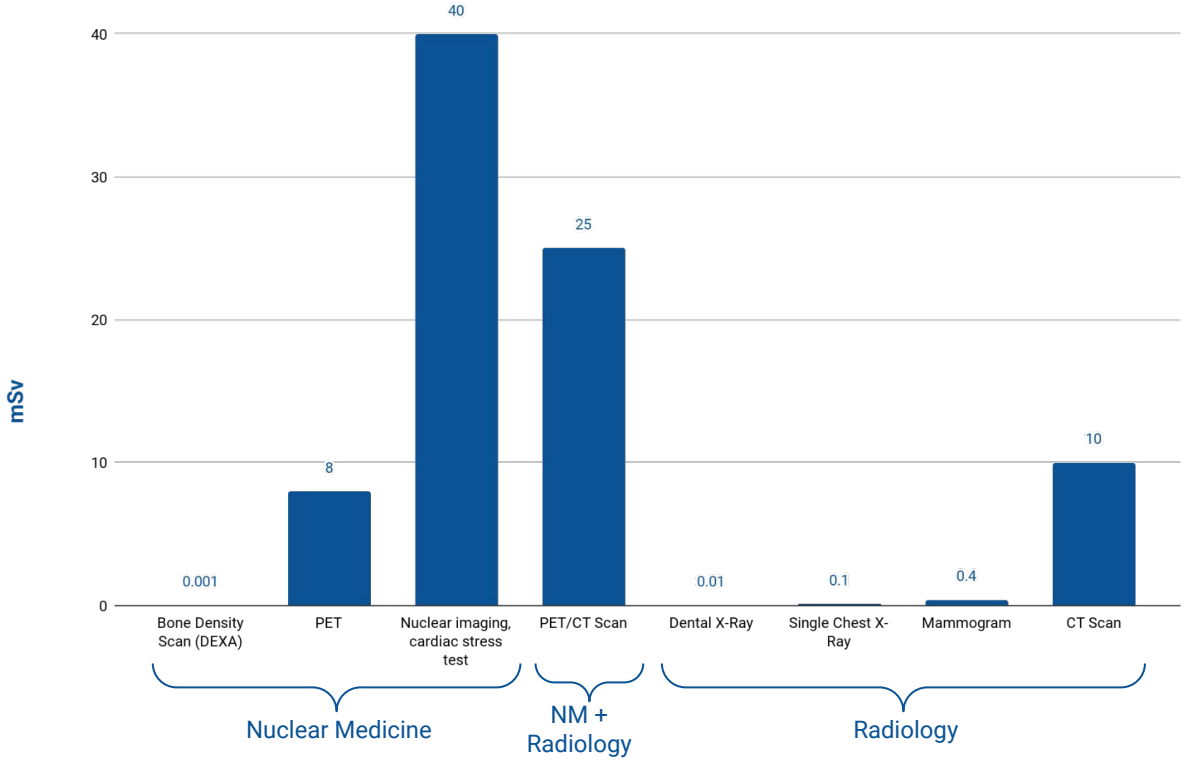
choice.com.au

Radiation Risk of Medical Imaging

Radiation doses in medical imaging are typically expressed as **millisieverts (mSv)** defined as *'the average accumulated background radiation dose to an individual for 1 year, exclusive of radon, in the United States'*. **1 mSv** is the *dose* produced by *exposure* to **1 milligray (mG)** of radiation. For reference, the average yearly background radiation dose (primarily from radon gas in a home) is **around 3 mSv.**

The radiation exposure a patient receives will depend on the type of examination and the purpose of the imaging study. Generally, plain **X-rays** and **mammography** give a lower radiation dose than **CT**. The highest doses of radiation can be received from **PET/CT** scan and **cardiac stress test**. **Ultrasound** and **MRI** do not use or produce ionising radiation.

Radiation Exposure during Nuclear Medicine vs Radiology Procedures



Sources: McEachen et al. CardioVascular and Interventional Radiology (2015)

Diseases That Can Be Tested by Different Types of Imaging

X-Ray

Bone fractures
Arthritis
Osteoporosis
Infections
Breast cancer
Swallowed items
Digestive tract problems

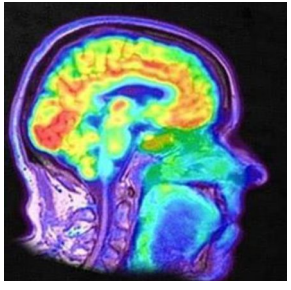
CT

Injuries from trauma
Bone fractures
Cancers
Vascular disease
Heart disease
Infections
To guide biopsies

MRI

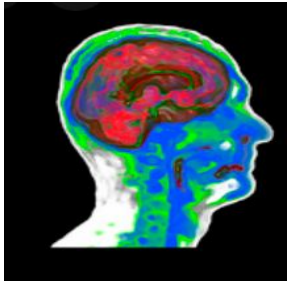
Aneurysms
Multiple Sclerosis
Stroke
Spinal cord disorders
Tumours
Blood vessel issues
Joint or tendon injuries

PET



Cancer
Heart disease
Coronary artery disease
Alzheimer's disease
Seizure
Epilepsy
Parkinson's disease

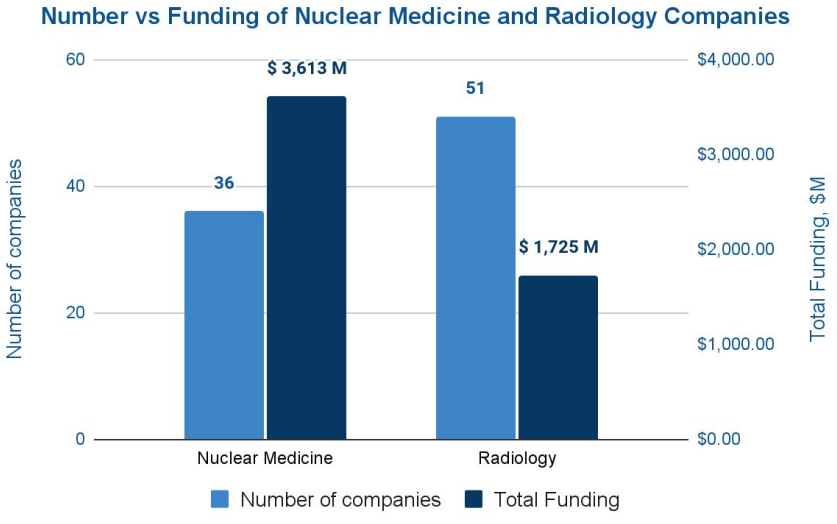
PET/CT



Cancer
Infection
Inflammation
Malignancy

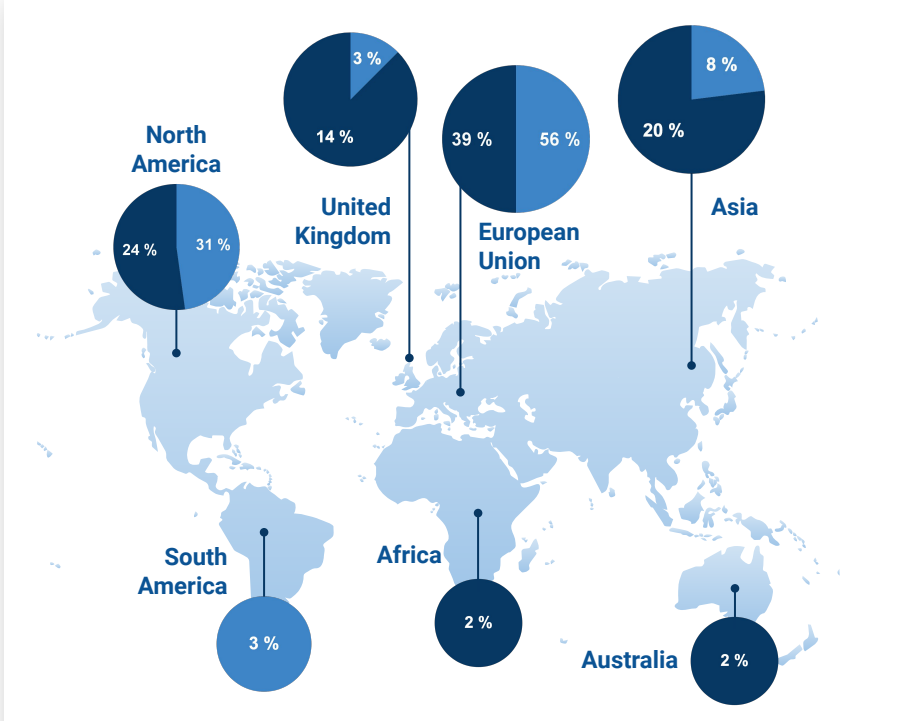
Sources: blog.radiology.virginia.edu

Nuclear Medicine vs Radiology: Business Trends



In the presented market overview, there is a higher number of companies that apply AI for radiology compared to the number of companies using nuclear medicine technology. Despite a smaller number of **nuclear medicine-oriented companies, their total funding is more than two-fold higher** compared to the radiology-specialised field.

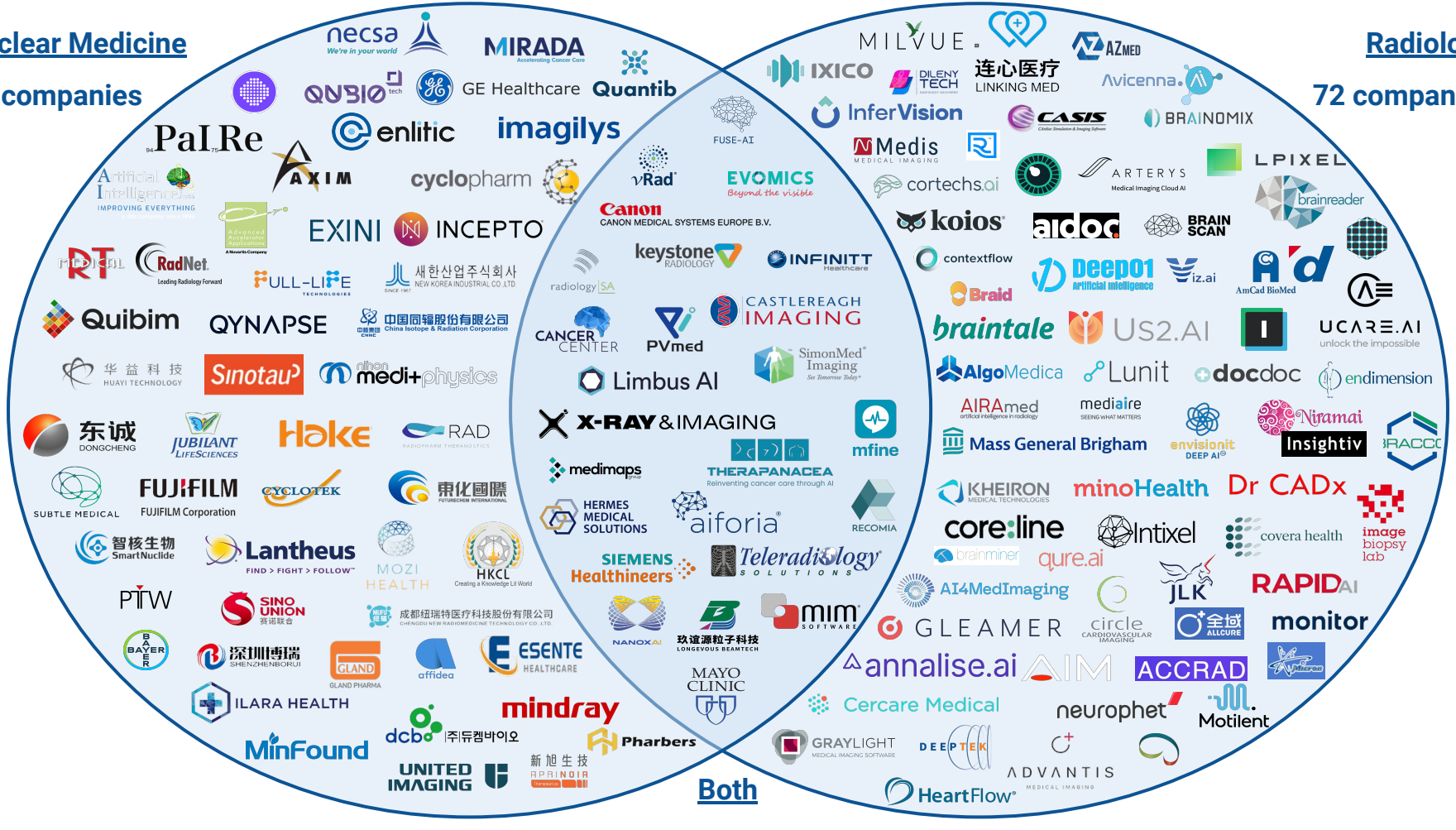
This drastic difference in total funding could be explained with a general tendency of huge tech companies, such as **Siemens Healthineers,** to lean towards nuclear medicine solutions in equipment and image analysis.



Percentage value demonstrates the fraction of companies within the category of nuclear medicine or radiology individually. Sector size within one chart schematically shows the ratio between factual number of companies in two categories.

Nuclear Medicine

56 companies



Radiology

72 companies

Both

26 companies

AI Applications in Nuclear Medicine

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AI and NM/Radiology Industry Overview

Nuclear medicine uses advanced imaging equipment and radiopharma with targeted combination function to carry out clinical diagnosis, disease treatment, and biomedical research. It is an important field of the application of nuclear science and technology in medicine.

The application of AI in nuclear medicine/radiology lies in image aided diagnosis, target delineation, absorption calculation, and radiopharma drug discovery.

Radio Isotope	Radiopharma
Radiopharmaceuticals are composed of radioisotopes and molecular reagents, acting on specific organs and tissues. They are used for imaging diagnosis and treatment. They are mainly used for **myocardial imaging and diagnosing of myocardial and neurodegenerative diseases, and therapeutic evaluation and treatment of malignant tumours.**	A nuclide is an atom with a certain number of protons and neutrons. **Isotopes are a group of nuclides with the same proton number but different neutron numbers.** Radioisotopes refer to unstable isotopes with radioactive properties. During the decay of radioisotopes, they can be emitted or transmitted in the form of particles, including rays of different types and energies such as αray and βray.

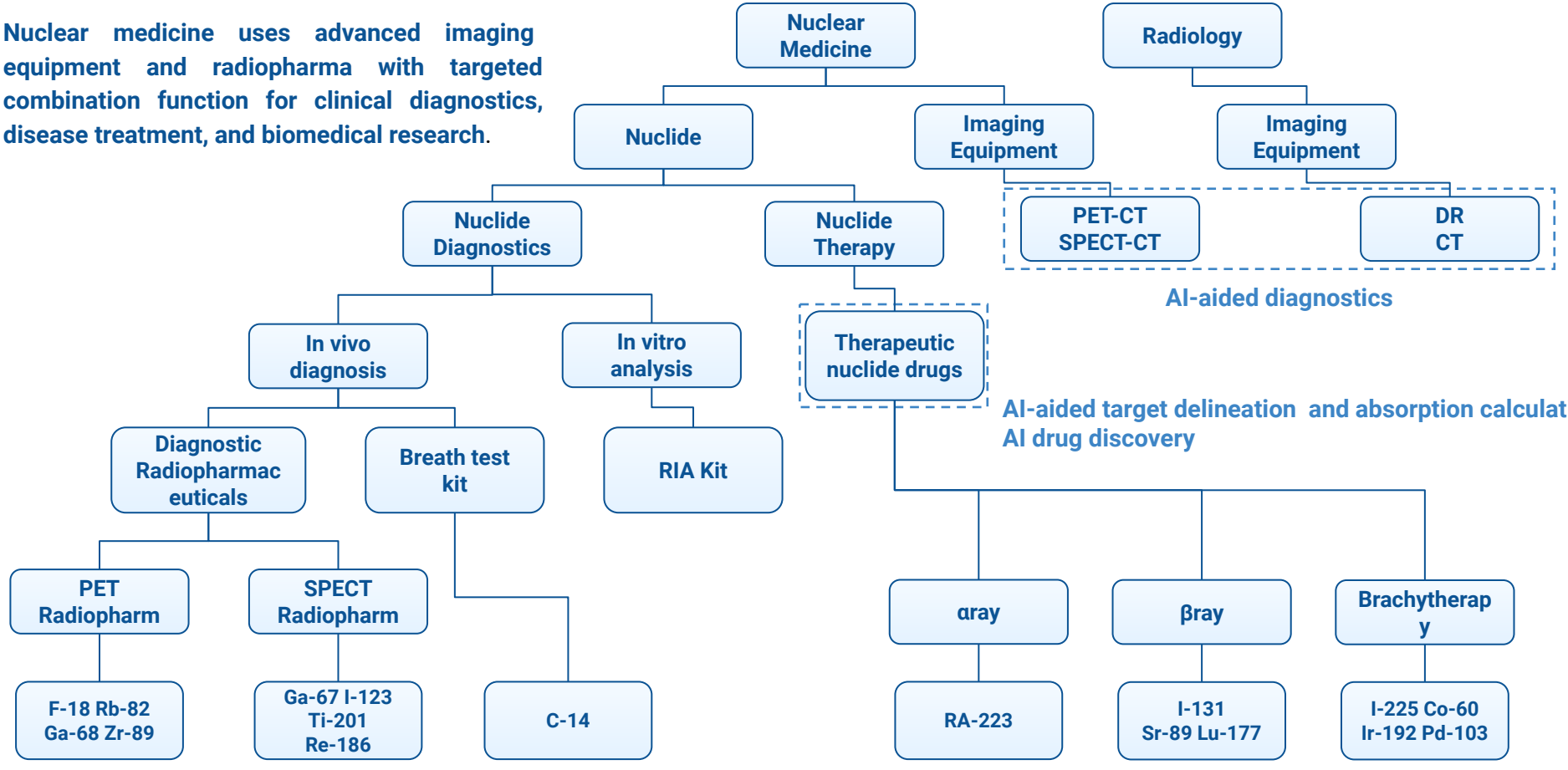
In terms of **imaging diagnosis**, radioisotopes used in diagnostics should have a **short half-life and strong penetrability**. The **γray** has strong penetrability and is easily measured by the detector. The radioisotopes commonly used in nuclear medicine diagnostics mostly generate rays directly or indirectly to facilitate detection and imaging analysis.

In terms of **treatment**, radionuclides for treatment are released in the process of decay αray and βray, with strong ionising radiation effect. It has a strong killing effect on tumour cells or abnormal proliferating tissues.

Sources: 2020 China Nuclear Medicine Industry Overview Report, Leadleo

AI and NM/Radiology Industry Overview

Nuclear medicine uses advanced imaging equipment and radiopharma with targeted combination function for clinical diagnostics, disease treatment, and biomedical research.

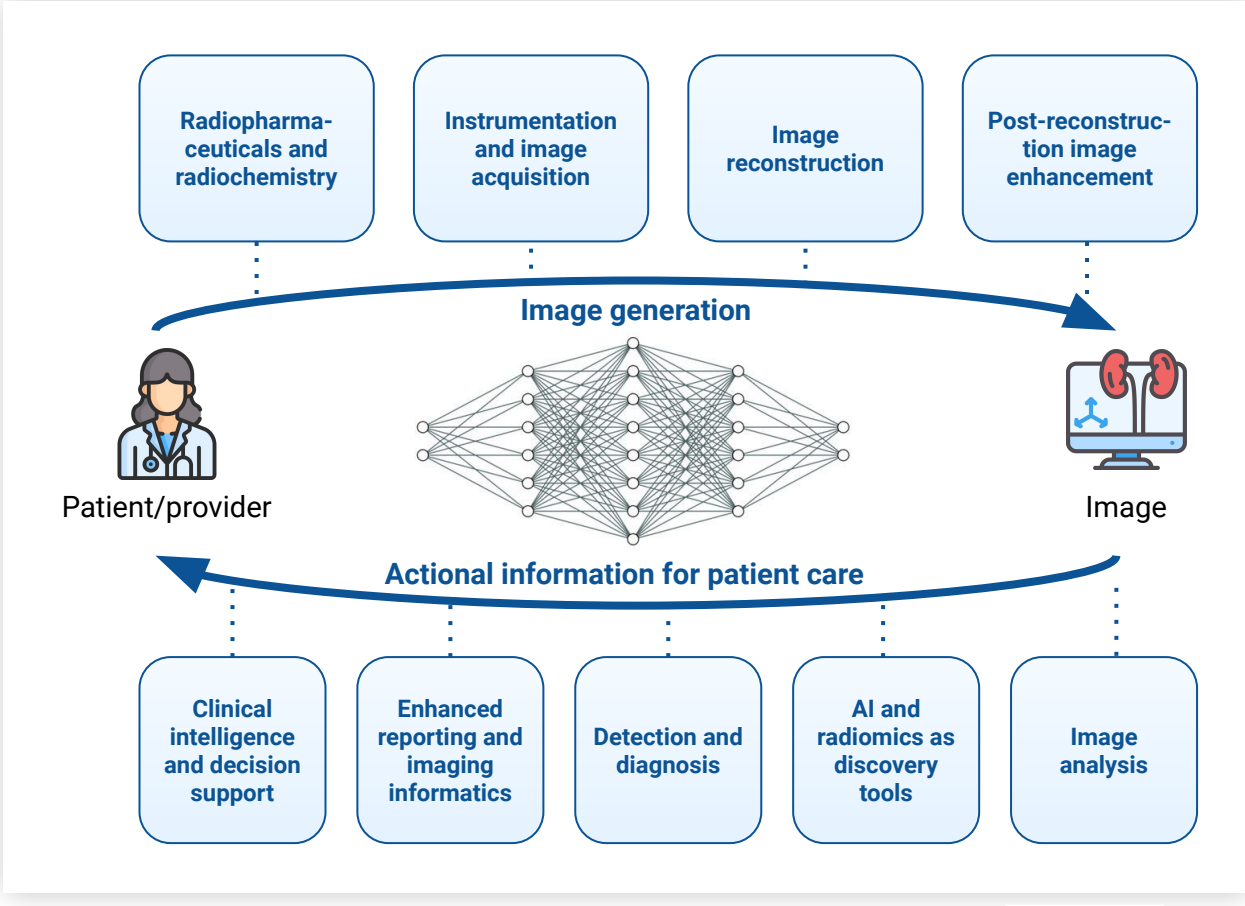


Sources: 2020 China Nuclear Medicine Industry Overview Report, Leadleo

AI Applications in Nuclear Medicine

Artificial Intelligence has numerous implementations in the field of nuclear medicine. It can be implemented for **routine tasks** such as planning of examinations, the detection of pathologies and their quantification, and manual research for additional information in medical records and textbooks, which takes too much time for physicians, as well as some **special applications** such as 'super diagnostics' and precision medicine.

A typical medical imaging workflow can be divided into four steps: **1) planning and optimisation, 2) scanning and reconstruction, 3) interpretation, and 4) reporting and clinical decision support**. Each step could be improved, accelerated, or completely automated with the help of AI.



Sources: The Journal of Nuclear Medicine

AI Applications in Nuclear Medicine

- Patient selection and scheduling
- Procedure selection
- Patient preparation
- Dosimetry planning
- Research of patient information (EHR)
- Checking of contra-indications (allergies)

- Faster image acquisition
- Better image quality
- Automated image reconstruction and post-processing
- Dose reduction
- Real-time detection of unexpected finding
- Creating of fusion images (PET/CT and PET/MRI)

- Detection of pathologies
- Classification and differential diagnosis of pathologies
- Segmentation and quantification
- Prioritisation

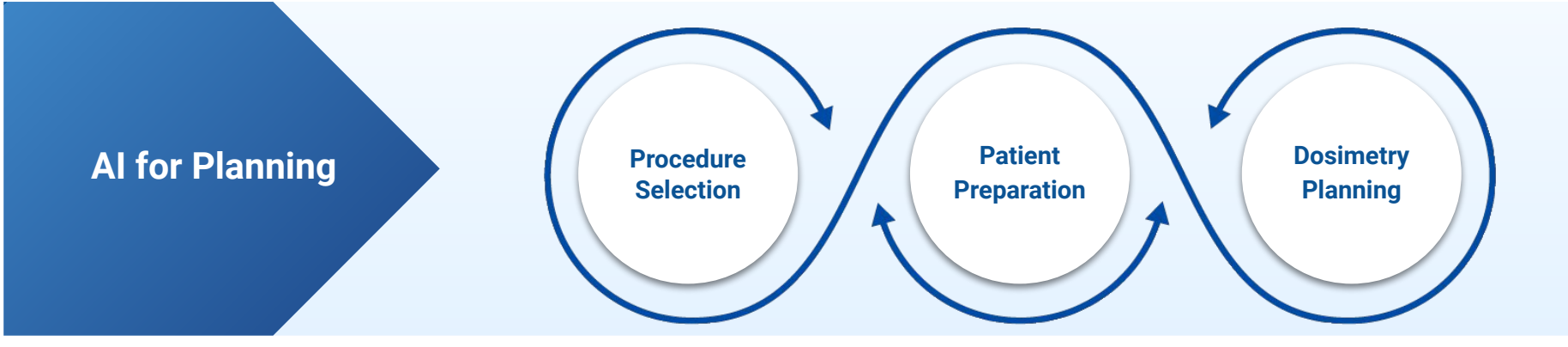
- Automated reports generation
- Automated including of recurring secondary findings in report
- Treatment efficacy and disease outcome predictions
- Research of medical knowledge in complicated cases
- Automated translation

Sources: The Journal of Nuclear Medicine

AI for Planning of Nuclear Medicine Procedure

Artificial Intelligence can be implemented from the first steps of the **nuclear medicine** procedure – planning.

The nuclear medicine procedure requires specific **preparations of the patient** (such as fasting before the scan, cessation of insulin if diabetic, etc.), which has been challenging and requires highly skilled human resources to juggle many of these requirements. Another crucial step is **dosimetry planning**, which consists of imaging at various time points, image processing, and mathematical calculations. These are technically demanding and commonly regarded as complicated clinical assignments for nuclear medicine experts but can be reassigned to the sophisticated AI system. Overall, **Artificial Intelligence can help optimise patient scheduling, procedure selection, patient prescan preparation, and pre-imaging/treatment dosimetry planning during the planning stage of nuclear medicine procedures**. The AI implementation on this step has **many benefits**, such as increased recruitments, reduced number of expensive PET scans in a clinical trial, and reduction of radiation dosimetry prediction error.



Sources: The Journal of Nuclear Medicine, Emerging role of Artificial Intelligence in nuclear medicine

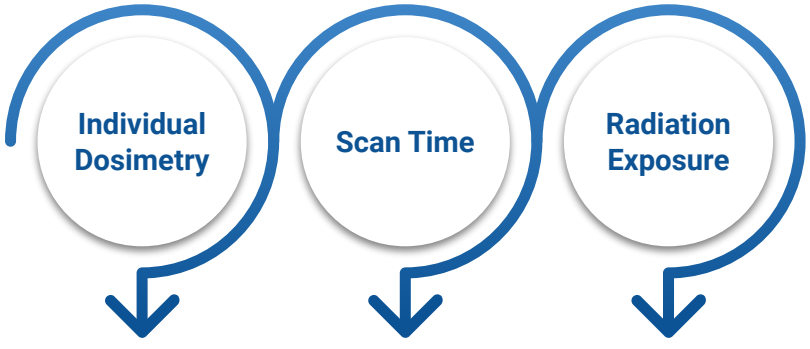
AI for Optimisation of Nuclear Medicine Procedure

Modern nuclear medicine equipment has already started the implementation of various AI approaches that assist with optimisation of **image quality**, **scan time,** and **radiation exposure** during diagnostic nuclear medicine procedures.

For therapeutic procedures, AI also can be useful for **pre-therapeutic** and **post-therapeutic dosimetry** by using organ and tumour segmentation, as well as prediction of either organ or tumour dose using single-point imaging.

Some patients require **additional imaging** or **delayed imaging** during PET and SPECT, for example, in case of brain metastasis suspicion. This decision is usually taken by a doctor; however, Deep Learning AI model can assist in decision-making by predicting or scoring the likelihood of a brain metastasis actually being present.

The **amount of radioisotope** to be injected is currently calculated based on body weight, which can lead to excess radiation or excessive noise and suboptimal image quality at lower radiation dose. With the use of patient demographic data, an AI-based radioisotope dosage system may be trained to recommend the patient-specific needed activity in a much more exact manner.



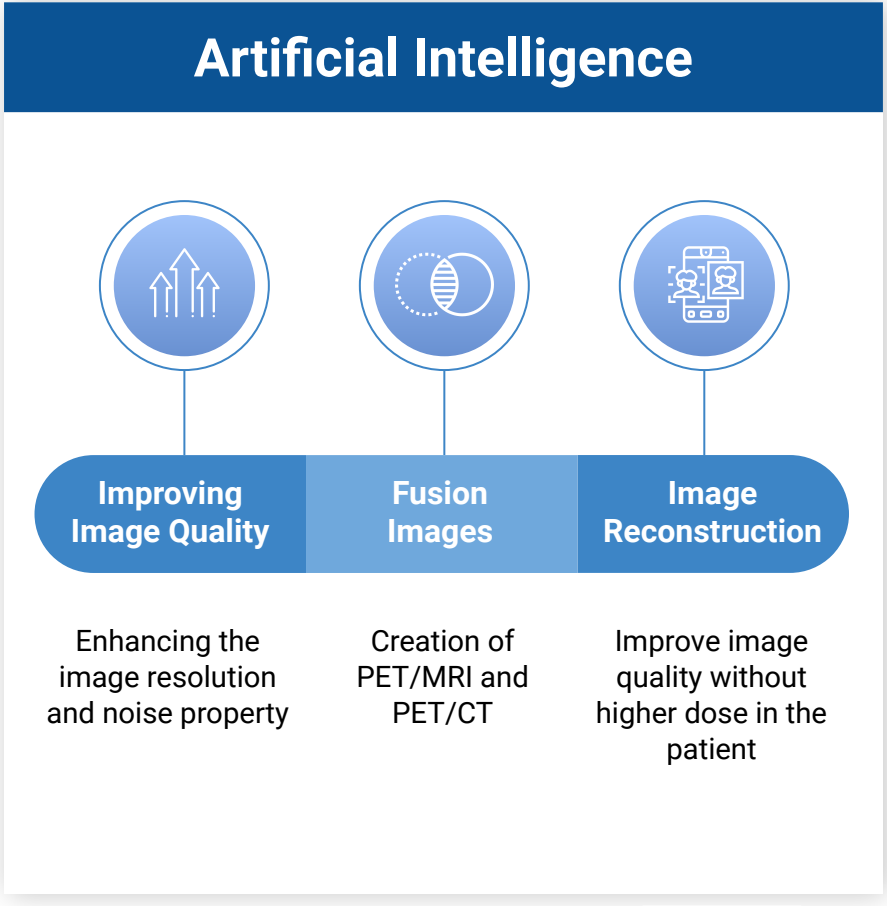
Sources: The Journal of Nuclear Medicine, Emerging role of Artificial Intelligence in nuclear medicine

AI for Scanning and Image Reconstruction

Many modern **scanners** are already equipped with Machine Learning approaches for overcoming such challenges as balancing act between radiation doses, longer imaging times, low image count density, low signal-to-noise ratio, high partial volume effect, and low spatial resolution since their inception. Additionally, the **reconstruction of nuclear medicine images** involves various computationally intensive steps, which can be solved by AI implementation.

AI is helpful for **improving image quality**, for example, by enhancing the image resolution and noise property of PET scanners with large pixelated crystals by Convolution Neural Networks (CNNs) or Generative Adversarial Networks (GANs). It also helps shorten the image acquisition time and results in higher patient throughput.

The **fusion images**, such as PET/MRI, are essential in modern diagnostics. However, the acquisition of such photos has some challenges, for example, MRI-based attenuation correction in PET for accurate PET imaging and quantification in PET/MRI. The Deep Learning methods help to overcome this challenge by the synthetical generation of a radiation attenuation map directly from MRI.



Sources: The Journal of Nuclear Medicine, Emerging role of Artificial Intelligence in nuclear medicine

Evomics Medical-A Leading Nuclear Medicine Company

EVOMICS
Beyond the visible

- **Evomics Medical**, a MedTech company specializing in nuclear medicine, is dedicated to creating a closed loop **integrating nuclear medicine diagnosis and therapeutics by developing targeted radiopharmaceuticals and AI-driven software for nuclear medicine imaging**
- Built on the unique strengths of nuclear medicine in specific disease areas, the **company focuses** on the development in the field of **oncology, cardiovascular and neurodegenerative diseases.**
- Led by world-renowned nuclear medicine experts and pharmaceutical industry veterans with extensive and successful track record, the company, which is **based in Vienna, Austria** and **Shanghai, China** and runs offices in several regions around the world
- The company has three units, namely, **radiopharmaceutical development, AI driven imaging diagnostic development** and **translational medicine research**

1

Targeted radiopharmaceuticals

In-license and develops independently a suite of radiopharmaceuticals in the field of oncology.

2

AI imaging diagnosis

Develop several medical software products in oncology, coronary heart disease, Alzheimer's disease and other fields.

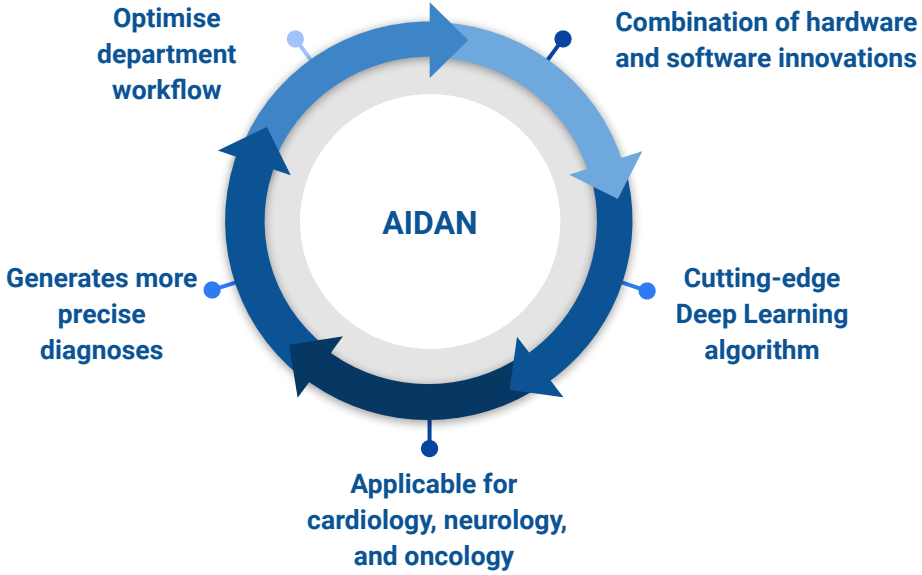
3

Translational medicine research

Provide standard radiomics and imaging genomics analysis platforms in collaboration with more than 30 hospitals.

AI for Optimisation, Scanning, and Image Reconstruction

Siemens Healthineers is a healthcare technology company that provides diagnostic and therapeutic products and services. In 2020, the Food and Drug Administration (FDA) cleared Siemens AIDAN Artificial Intelligence technologies for PET/CT scanners. AIDAN accelerates operational efficiency and creates an elevated patient workflow that generates more precise diagnoses and helps transform care delivery. For molecular imaging professionals, AIDAN uses powerful Artificial Intelligence to generate real impact.



Biograph Horizon PET/CT Scanner

Sources: Siemens-healthineers.com

AI for Optimisation, Scanning, and Image Reconstruction

FlowMotion AI

FlowMotion AI automatically detects patients anatomical structures and applies disease-specific protocol parameters based on individual requirements. Manual protocol entry and alignment are no longer necessary with FlowMotion AI.

OncoFreeze AI

During a PET/CT exam, patient respiratory motion degrades picture quality. OncoFreeze AI provides for the capture of PET/CT pictures that are almost devoid of respiratory motion, while utilising 100% of the PET counts obtained, with no additional time spent on the exam and no need for a respiratory belt.

PET FAST WorkFlow AI

PET FAST WorkFlow AI automates and streamlines post-scan operations, including fast image transmission and auto data export, as well as the creation of picture archiving and communication system (PACS)-ready data ranges.

Multiparametric PET Suite AI

PET FAST WorkFlow AI automates and streamlines post-scan operations, including fast image transmission and auto data export, as well as the creation of picture archiving and communication system (PACS)-ready data ranges.

Sources: Siemens-healthineers.com

AI for Image Analysis and Interpretation

Image analysis and **interpretation** are the most critical tasks in nuclear medicine as it significantly influences the further fate of the patient.

AI for image analysis is used for **fully automated pathology detection** (e.g. in bone or thyroid scans) or working in the **background mode** that could alert the human interpreter to possibly overlooked findings.

Additionally, AI assistant is able to **detect diseases in their early stages**. For instance, Deep Learning models can detect early Alzheimer's disease and mild cognitive impairment. CNN with InceptionV3 architecture could make an Alzheimer's disease diagnosis with 82% specificity at 100% sensitivity based on PET/CT scans and outperformed human interpreters. However, even models with such excellent results should remain under human supervision.

In the future, AI assistants will be able to **work with the raw data before the reconstruction** and raise alerts during the scan time. This will allow modifying or extending the planned scan protocol to accommodate the unexpected finding.

AI-driven Image Analysis in Nuclear Medicine

Image Reading

1. Classification

   Processing of predefined anatomical region (e.g. cerebral FDG PET)

2. Semi-automated reporting

   Exclusion of physiological tracer uptake (e.g. kidneys in PSMA PET)

3. Whole-body tumour segmentation

   Fully automated segmentation of all tumour lesions in molecular imaging data

Technological

1. Attenuation correction

   CT free attenuation correction of PET images

2. Image reconstruction

   Artefact free reconstruction (e.g. ultra-low dose PET)

3. Anatomical landmarking

   Automated positioning for visualisation or optimised scan speed

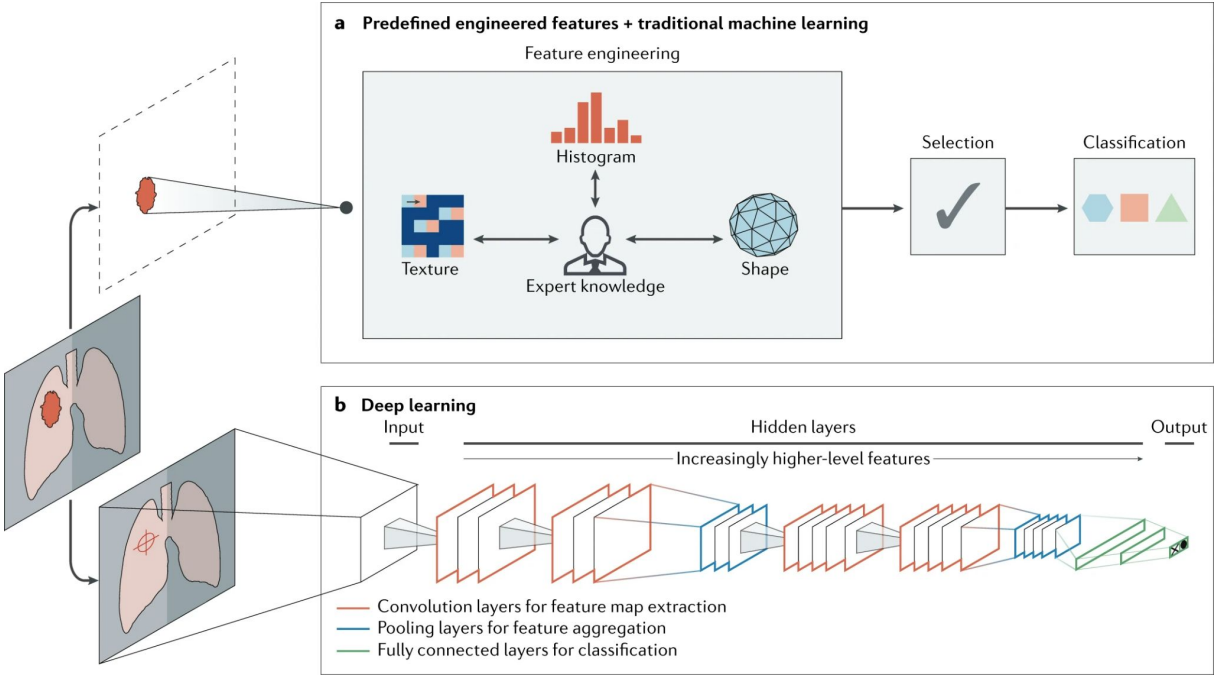
Sources: The Journal of Nuclear Medicine, Emerging role of Artificial Intelligence in nuclear medicine

Artificial Intelligence Methods in Medical Imaging

The scheme represents **two AI methods** for such image analysis tasks as classifying tissues and discovering malignant or benign cells.

The first technique uses **expert knowledge to extract engineered properties** from regions of interest. Tumour volume, form, texture, intensity, and location are such characteristics. The **most robust features** are selected and **fed into ML classifiers**.

The second technique relies on **DL** and does **not require region annotation**; instead, localisation is generally enough. The **DL model** has numerous layers where feature extraction, selection, and final classification are all made simultaneously.



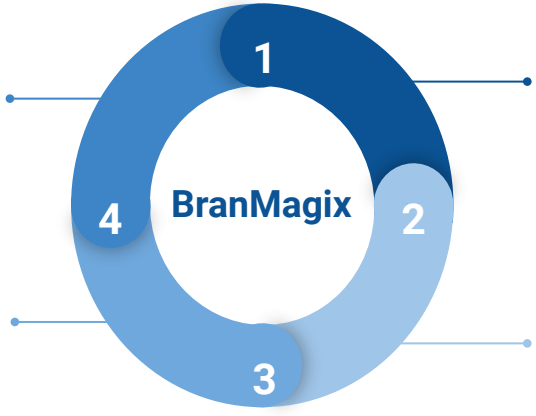
Sources: Nature Reviews Cancer

AI for Image Analysis and Interpretation

Imagilys is a Belgium company that brings cutting-edge neuroimaging techniques from the lab to the patient's bedside. Their neuroimaging software suite, **BranMagix**, assists customers in better **diagnosing** and **treating** the most severe neurological disorders. Modules exist of fusion tools, atrophy quantification, fMRI analysis, diffusion analysis, perfusion analysis, and longitudinal follow-up for multiple sclerosis and other chronic brain diseases.

Types of modules in the software:

- Viewer Module
- fMRI Module
- Diffusion Module
- Perfusion Module
- Longitudinal Follow-up Module
- SurferMagix Module
- BrainMagix SPM Viewer



EXPORT

Export your results as Portable Network Graphics (PNG) images.

LOCALISE

Localise your activations in an atlas.

READ

Read Statistical Parametric Mapping (SPM) and Neuroimaging Informatics Technology Initiative (NIfTI) images.

SHARE

Share results even without Statistical Parametric Mapping (SPM) software suite installed.

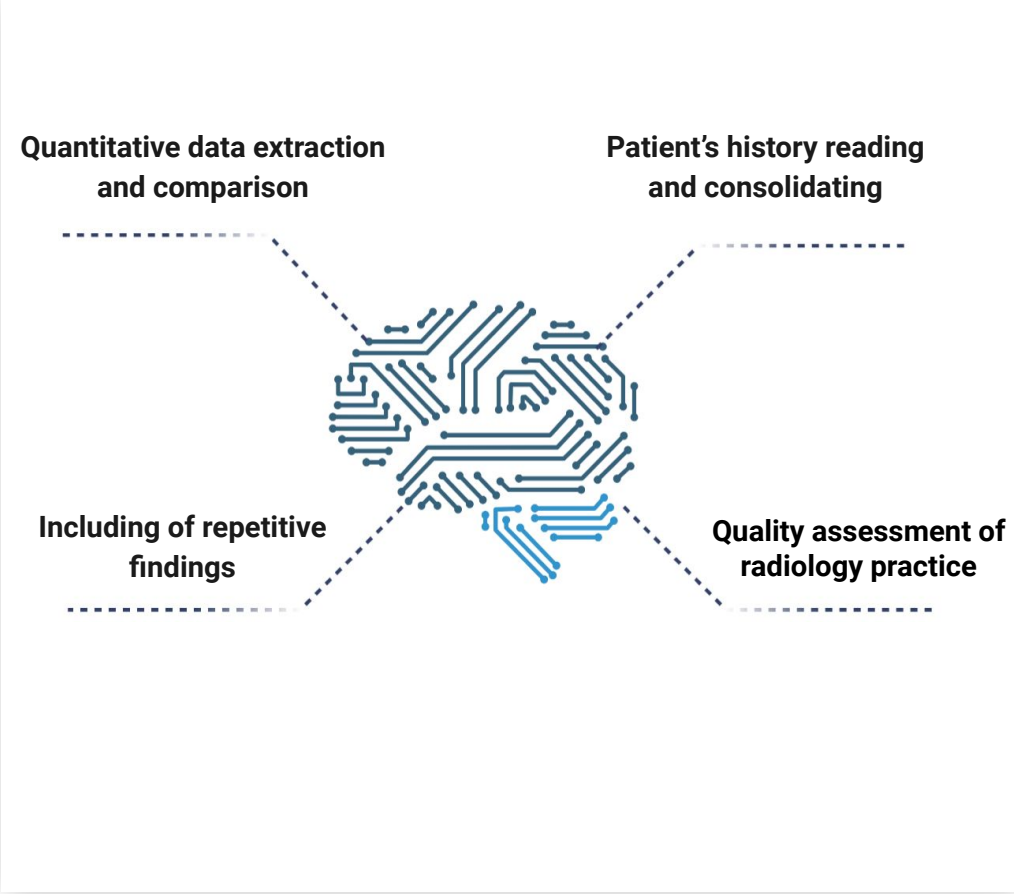
Sources: Imagilys

AI for Report Generation

During the **reporting stage**, AI has the potential to save the time of the nuclear medicine specialist by **automating the execution of more routine tasks in the report generation**. Such tasks as quantitative data extraction and comparison, reading the patient's history from the electronic medical record and consolidating the history in the report take a long time and result in reduced output from a nuclear medicine physician. AI techniques may be used to alleviate this load, allowing the expert to focus on other essential duties such as interpretation of findings and expert opinion.

Additionally, AI assistants can detect and automatically include **recurring secondary findings** in the report, often tedious for experienced medical professionals.

Natural Language Processing (NLP) has significant potential in nuclear medicine report processing. It can be helpful for diagnostic surveillance, cohort building for epidemiologic studies, query-based case retrieval, and quality assessment of radiology practice and clinical support services with a level of evidence.



Sources: The Journal of Nuclear Medicine, Emerging role of Artificial Intelligence in nuclear medicine

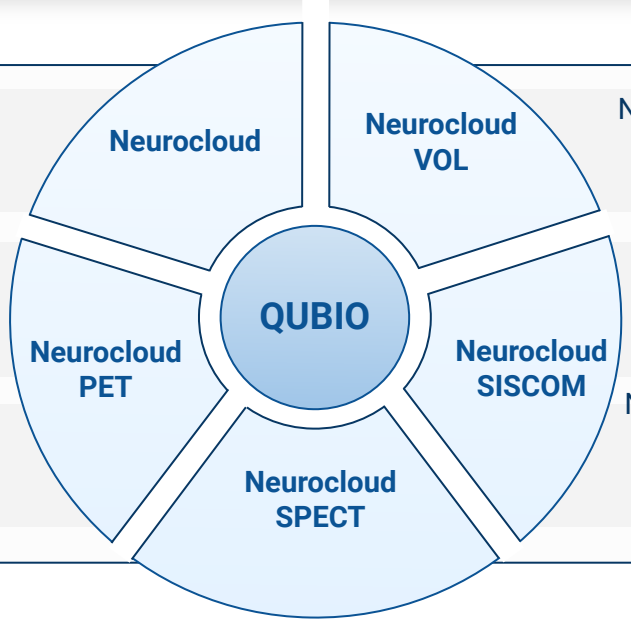
AI for Report Generation

Qubiotech is a Spanish company that develops **AI-assisted analysis of biomarkers in the PET, SPECT, MR, and CT neural images** and then **generates the custom report**. The platform instantly delivers quantitative biomarkers that allow the identification of problems where the human eye cannot perceive variations, allowing early diagnosis and patient monitoring, eliminating biases, and lowering the probability of false negatives.

Neurocloud is a cloud platform for the automatic processing of neuroimaging assisted by AI

Neurocloud PET is the software for the quantitative analysis of brain PET images

Neurocloud SPECT software performs co-registration of SPECT images with the patient's MRI



Neurocloud covers image analysis for nuclear medicine, neurology, radiology, and epileptology

Neurocloud VOL performs volumetric analysis for the quantification of atrophy and lesions in MR imaging

Neurocloud SISCOM is a platform that allows to accurately and fully automatically identify the epileptogenic focus in epilepsy patient

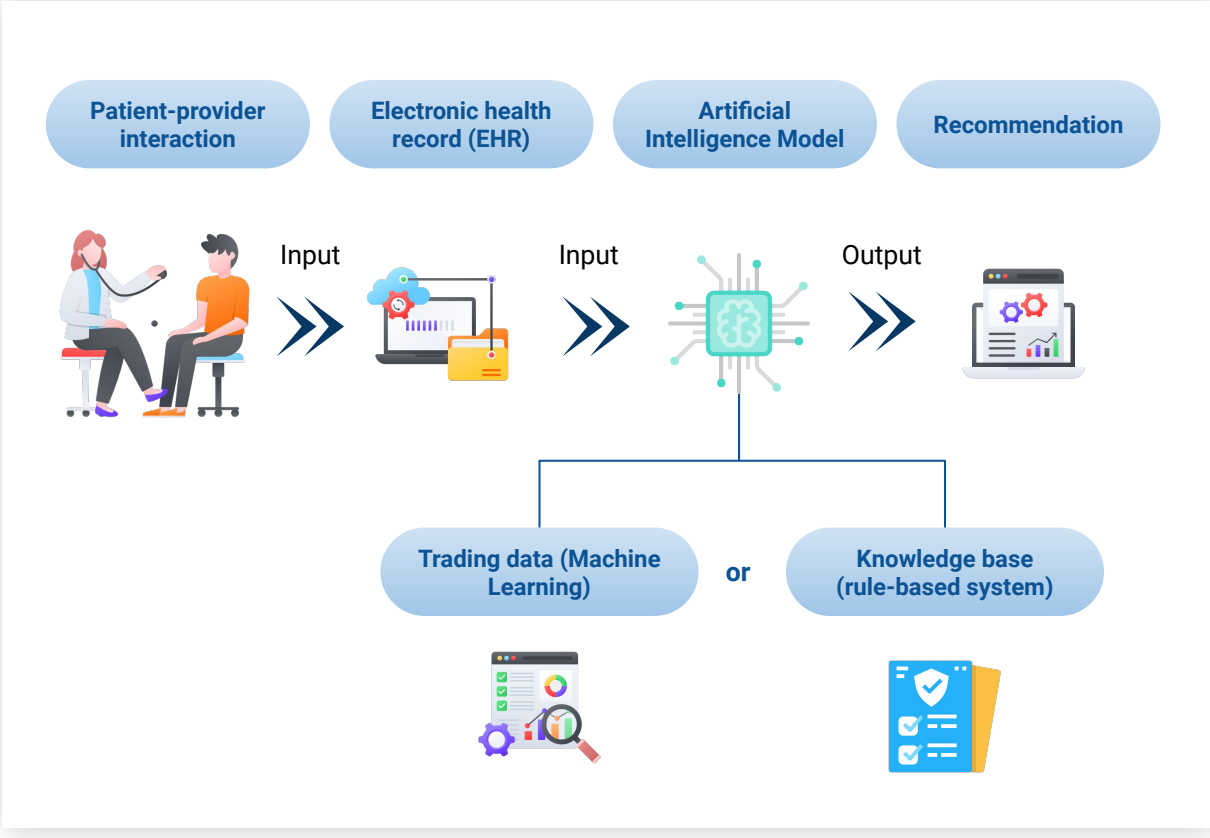
Sources: Qubiotech

AI for Clinical Decision Support System

Nuclear medicine imaging plays an essential role in **personalised medicine**. Such parameters as standardised uptake value (SUV), total lesion glycolysis (TLG), and PET Response Criteria in Solid Tumours (PERCIST) can be used for the **treatment efficacy and disease outcome prediction by the AI models**.

There are already existing prediction models for **outcome predictions in oncology**, such as overall survival (OS), progression-free survival (PFS), loco-regional recurrence, distant metastasis, treatment outcome, toxicity, and treatment selection that implement parameters extracted from nuclear medicine imaging.

The information extracted from myocardial perfusion imaging from the SPECT scans was used for the CNN model to **detect and predict obstructive myocardial disease**. This AI model overperformed the clinical specialists (AUC: 0.81 vs. 0.65) for predicting major cardiac events in a cohort of 2,619 consecutive patients.



Sources: The Journal of Nuclear Medicine, Emerging role of Artificial Intelligence in nuclear medicine

AI for Clinical Decision Support System

Qynapse is a French company that has developed AI-powered algorithms for the **analysis of medical images with CNS diseases**, **generating of the report based on the analysis**, and **prediction of disease progression**. **QyScore** is a neuroimaging analysis platform for both clinical routine and clinical trial settings while **QyPredict** is currently available only for researchers to improve targeted patient selection in clinical trials and prediction of disease progression in patients.

QyScore

- **FDA-cleared** and **CE-marked** neuroimaging software platform;
- Automated measures of **neuroinflammation** and **neurodegeneration;**
- Rapid automatic generation of **patient reports** after the image analysis;
- Decreases image reading variability and segmentation errors by **89%;**
- Can diagnose such diseases as **Alzheimer's and other dementias, multiple sclerosis, Parkinson's, and movement disorders.**

QyPredict

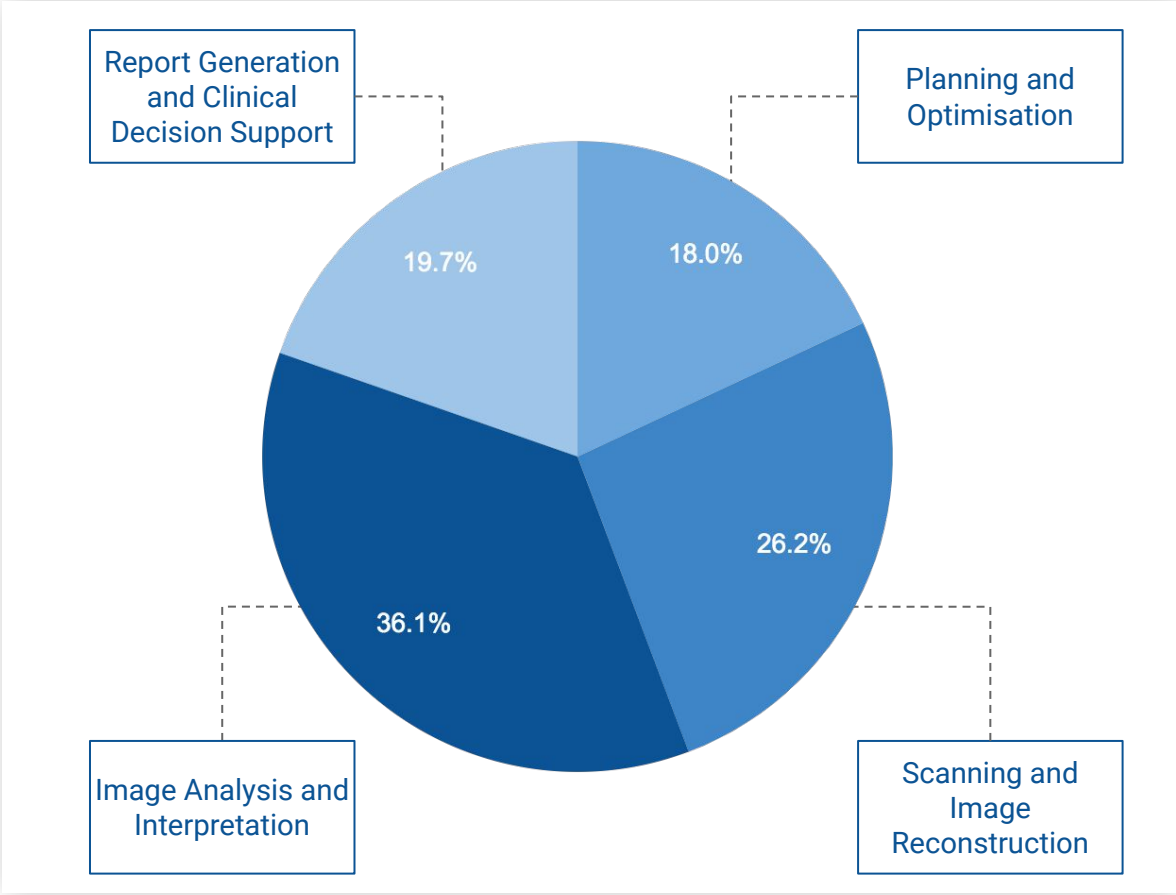
- The predictive **research-use-only** software platform;
- Automated **prediction of the disease progression** based on neuroimaging scans and clinical data;
- **Prediction of the onset** of a CNS disease;
- Increase the **likelihood of the success of the clinical trial** by adjusting patient selection and prediction of the clinical progression;
- Can be used for **personalised medicine**: the platform predicts a patient's disease trajectory, which would transform and improve timely intervention and treatment plans.

Sources: Qynapse

AI Applications in Nuclear Medicine: Business Trends

Most companies that develop AI systems for nuclear medicine applications invent **software for image analysis and interpretation**. This category is the broadest and takes **more than a third of all AI in nuclear medicine companies**. There are several reasons for the dominance of this category:

- The **high level of development of AI algorithms for image analysis** (especially medical images) leads to existing developments, algorithms, scientific literature, and even ready-to-use solutions that simplify the invention of new software.
- The **absence of the lack of professionals** and a broad community of experts.
- Sufficient amount of **appropriate data** for model training.
- **No need for any expensive additional equipment** (such as scanners).



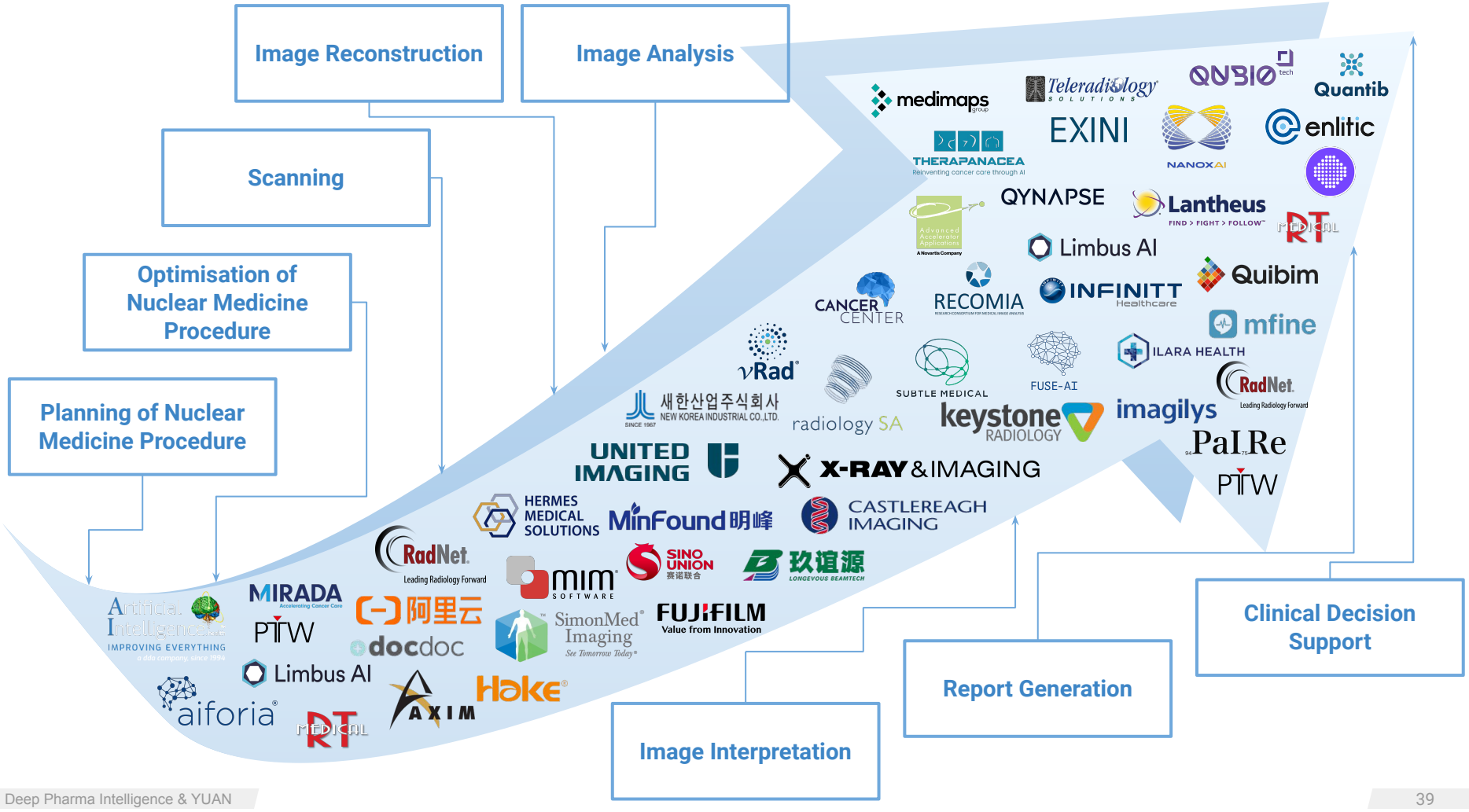


Image Reconstruction
Image Analysis
Scanning
Optimisation of Nuclear Medicine Procedure
Planning of Nuclear Medicine Procedure
Clinical Decision Support
Report Generation
Image Interpretation
medimaps
Teleradiology Solutions
QUBIO
Quantib
EXINI
NANOX.AI
enlitic
THERAPANACEA
Reinventing cancer care through AI
QYNAPSE
Lantheus
FIND > FIGHT > FOLLOW
RT MEDICAL
Advanced Accelerator Applications
A Novartis Company
Limbus AI
Quibim
CANCER CENTER
RECOMIA
INFINITT Healthcare
mfine
ILARA HEALTH
vRad
새한산업주식회사
NEW KOREA INDUSTRIAL CO.,LTD.
SINCE 1967
radiology SA
SUBTLE MEDICAL
FUSE-AI
RadNet
Leading Radiology Forward
keystone RADIOLOGY
imagilys
PaIRe
PTW
UNITED IMAGING
X-RAY & IMAGING
HERMES MEDICAL SOLUTIONS
MinFound 明峰
CASTLEREAGH IMAGING
RadNet
Leading Radiology Forward
mim SOFTWARE
SINO UNION 赛诺联合
玖逖源 LONGEVOUS BEAMTECH
Artificial Intelligence
IMPROVING EVERYTHING
a dda company, since 1994
MIRADA
Accelerating Cancer Care
PTW
阿里云
docdoc
SimonMed Imaging
See Tomorrow Today
FUJIFILM
Value from Innovation
Limbus AI
aiforia
RT MEDICAL
AXIM
Hake

Rise of AI in Nuclear Medicine

DEEP PHARMA INTELLIGENCE

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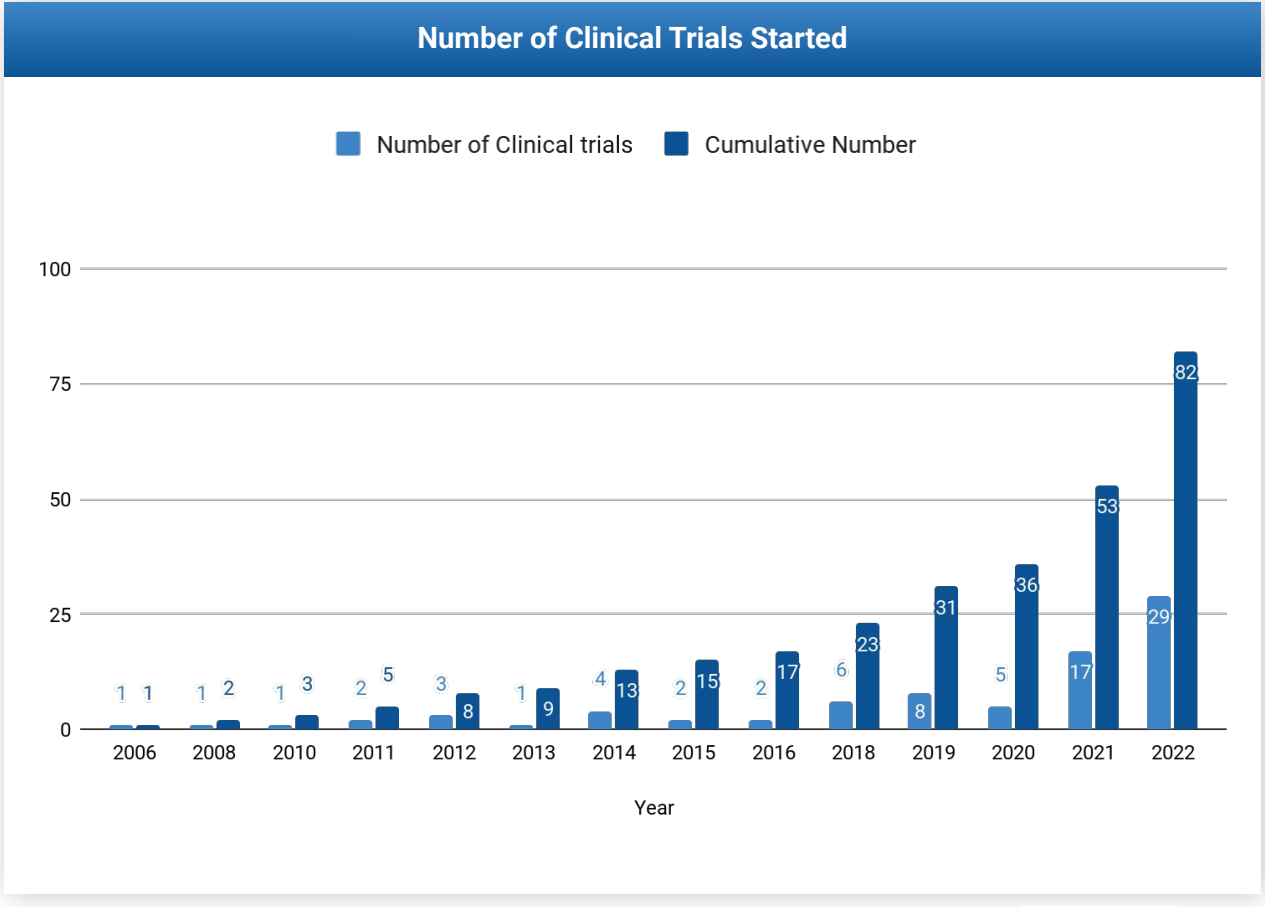
Rise of AI in Nuclear Medicine: Clinical Trials

The first clinical trial with AI technology for nuclear medicine started in **2006** titled 'Identification of Clinically Occult Glioma Cells and Characterisation of Glioma Behavior Through Machine Learning Analysis of Advanced Imaging Technology'. Over the years, more and more clinical trials with AI technology appeared. The **prominent rise was in 2021** when almost three times more clinical trials were started than in 2020. One of the reasons for this may be the **COVID-19 pandemic,** which provoked the active development of AI techniques for medical imaging. In this key, nuclear medicine imaging is not an exception.

The represented graph was obtained by calculating the number of clinical trials on clinicaltrials.gov over years.



Sources: ClinicalTrials.gov

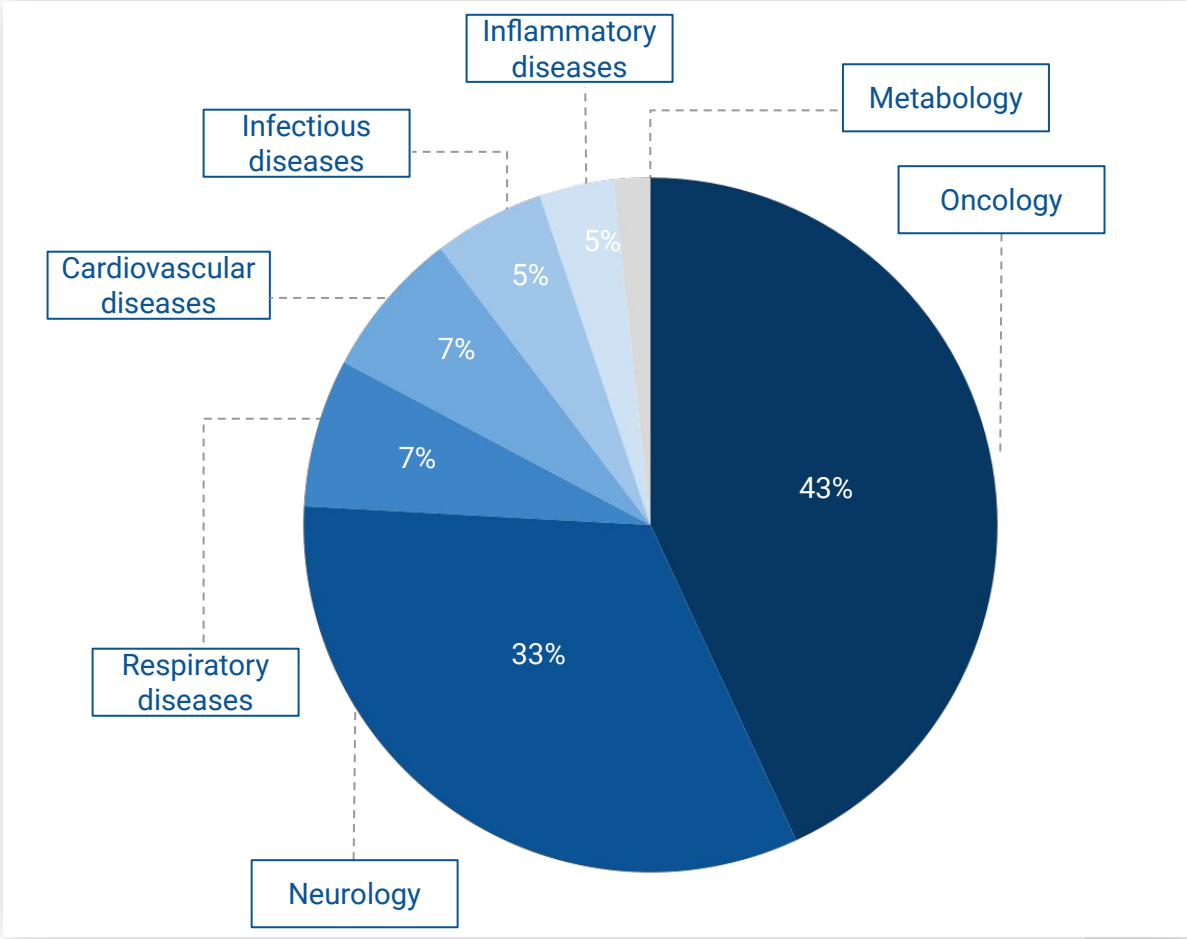
Rise of AI in Nuclear Medicine: Clinical Trials by Disease Area

AI tools are increasingly being applied in drug discovery against different disease areas. One of the most popular areas is **oncology**. With this growing global burden of oncology diseases, discovery of cancer treatment is one of the most significant public health challenges of the 21st century.

Neurology takes the second place, and 33% of clinical trials presented on the graph aim to develop drugs for the treatment of neurodegenerative diseases.

Also, a high percentage of programmes aim to develop drugs in the field of **respiratory diseases** the treatment of which requires the development of new targets.

Other areas that have fewer than 10 clinical trials are **cardiovascular**, **infectious, inflammatory, and metabology diseases**.



Sources: ClinicalTrials.gov

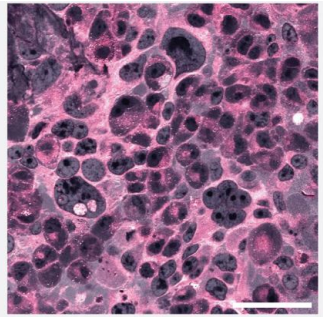
Top Applications of AI in Nuclear Medicine and Radiology: Classifying Brain Tumours

Patients with brain tumours are traditionally kept in the dark about their operation as are their doctors. They are both knowledgeable of the type of tumour present and the therapeutic options available to the patient. An imaging technology called **stimulated Raman histology (SRH)** was combined with the **convolutional neural networks** to improve current intraoperative pathology practice and do it in **less than 3 minutes**.

Freshly excised specimens are loaded directly into an SRH imager for image acquisition.

CNN, trained on over 2.5 million of SRH images, predicts brain tumour diagnosis in the operating room in under 150 seconds, an order of magnitude faster than conventional techniques.

1 **1. Image acquisition (~120 sec)**



SRH is an optical imaging method that provides rapid, label-free, submicron resolution, images of unprocessed biological tissues.

Stimulated Raman histology (SRH)

Convolutional neural networks (CNN)

2 **Image processing (~2 sec)**

3 **Intraoperative diagnostic prediction (~15 s)**

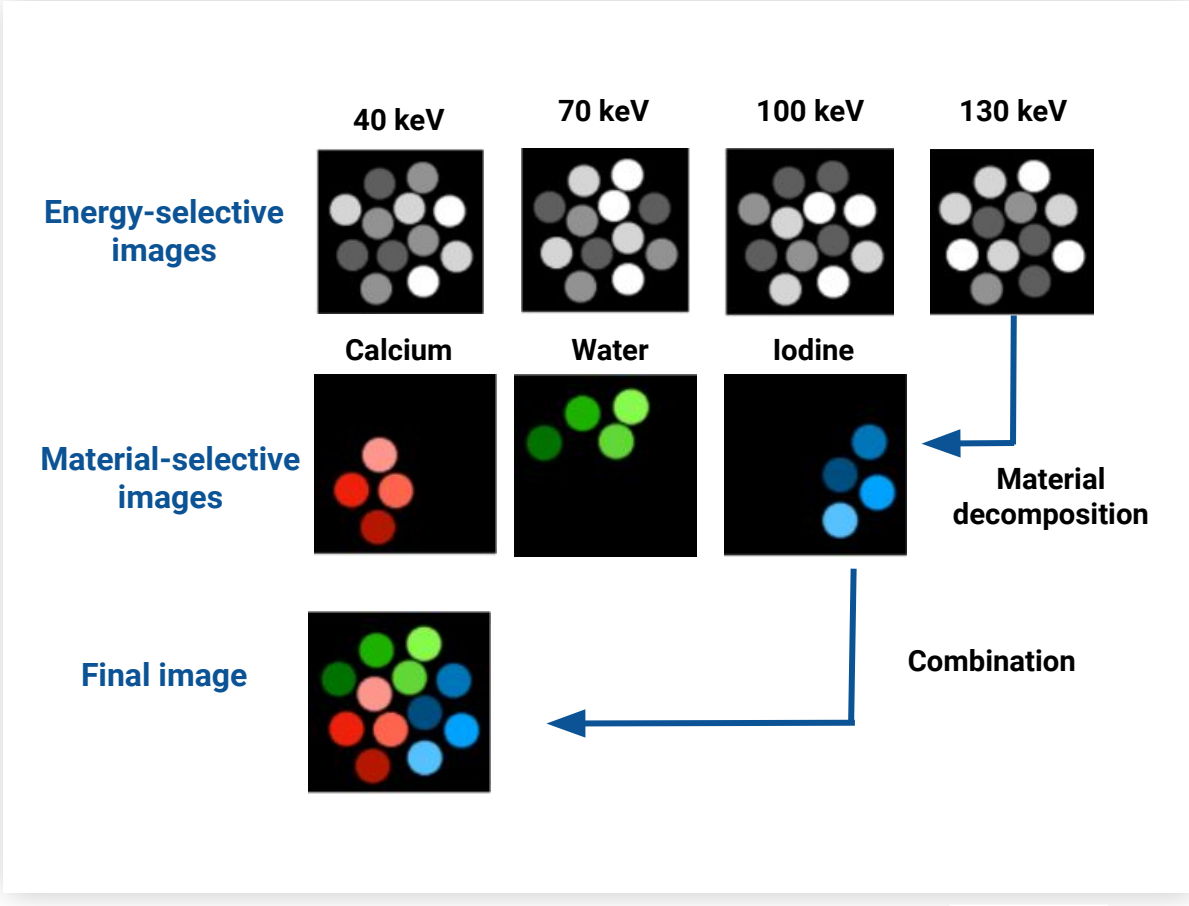
Sources: Hollon et al. Nature Medicine (2020)

Top Applications of AI in Nuclear Medicine and Radiology: Neurology

There are various limitations to current **CT technology**, including a trade-off between ionising radiation exposure and image quality. Artefacts such as **image noise** and **distortions grow** as dosage is reduced, impairing CT's already poor ability to distinguish between healthy and diseased tissues.

The world's first photon-counting CT (PCCT) scanner received European and FDA clinical approval **in 2021.** This method improves resolution dramatically, while lowering radiation dose and breaking through the traditional technical constraints of standard CT.

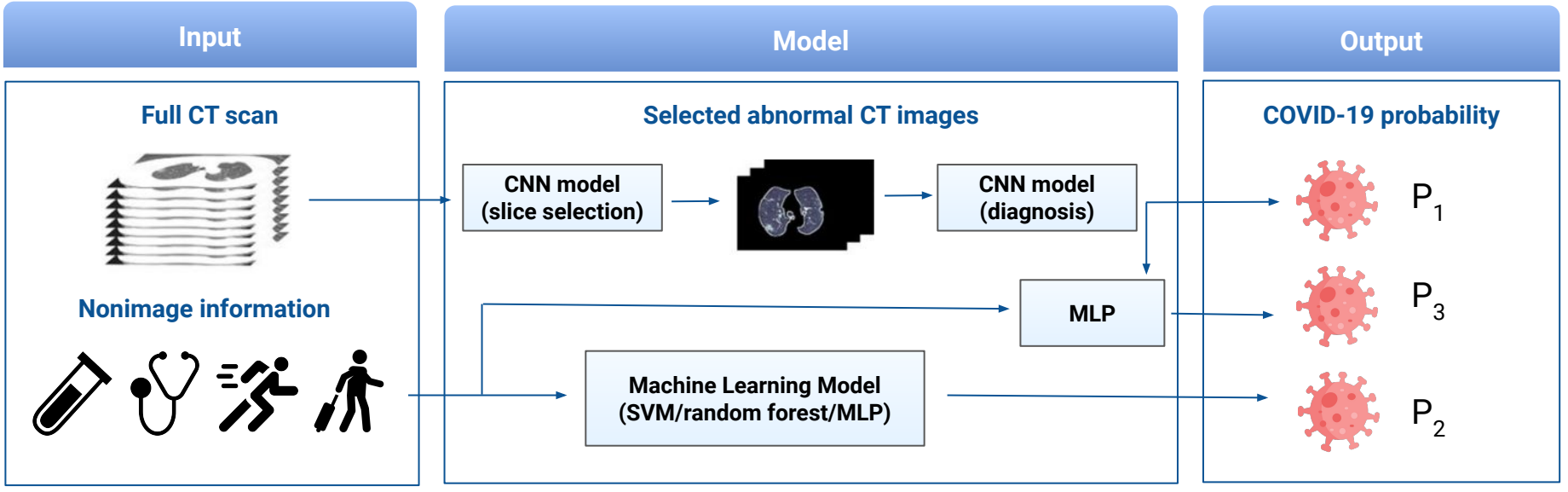
Energy-selective pictures are derived from the number of counts in each energy bin in photon-counting CT material decomposition. Material-selective images are generated using a **data-processing method,** known as material decomposition. The final image seen by radiologists is created by combining these images.



Top Applications of AI in Nuclear Medicine and Radiology: Second Opinion

AI algorithms can run in the background and provide a **second view** when radiologists disagree on a problematic medical image. This method helps radiologists learn to work with AI and recognise its benefits, while reducing decision-making stress. For detecting **COVID-19** in **CT scans**, **Mount Sinai Health System** in New York City deployed AI with a human professional to analyse radiology results as a '**second opinion**' alternative. They claim to be the first to detect new coronaviruses **using AI** and medical imaging.

Overall, these findings highlight the potential usefulness of a highly accurate AI system in the **rapid identification of COVID-19 patients**, which could support in the fight against the current disease pandemic. The proposed AI model could be a valuable screening tool for promptly diagnosing infectious disorders like COVID-19 without the need for a radiologist or physical tests.



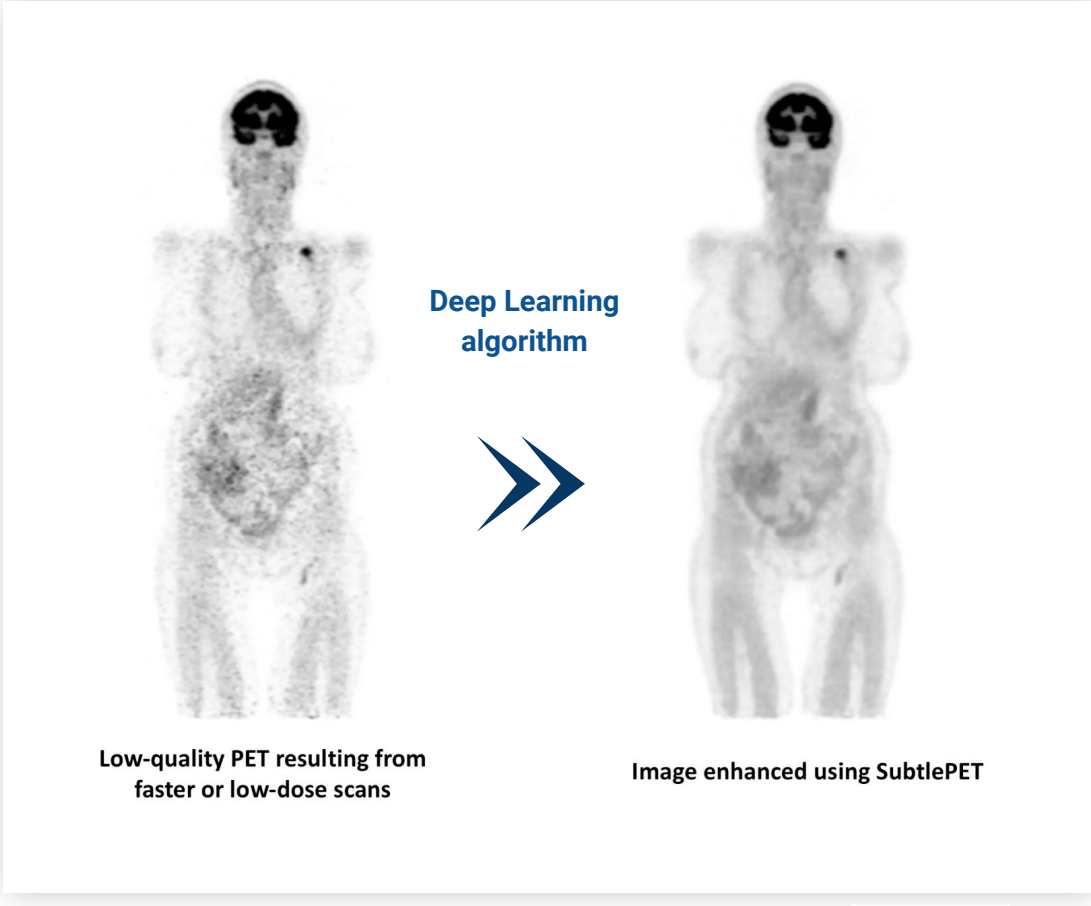
Sources: Mei et al. Nature Medicine (2021)

Top Applications of AI in Nuclear Medicine and Radiology: Dose Optimisation

PET/CT is widely employed in a variety of clinical settings, including the diagnosis of cancer and neurological problems. Because PET/CT is so important in determining systemic drug response, a large percentage of patients have more than one PET/CT scan per year, increasing their **radiation exposure**.

Radiation dose has been associated with a slight increase in patients' lifetime risk of developing cancer. In this situation, **AI** can be an optimising tool for assisting technologists and radiologists in selecting a personalised patient protocol, tracking the patient's dose parameters, and estimating the radiation risks associated with cumulative dose and the patient's susceptibility.

The **Subtle Medical** team managed to produce the same quality of imaging with an AI-enhanced 5-minute exam, while also reducing the required radiation dosage **up to 200-fold**.

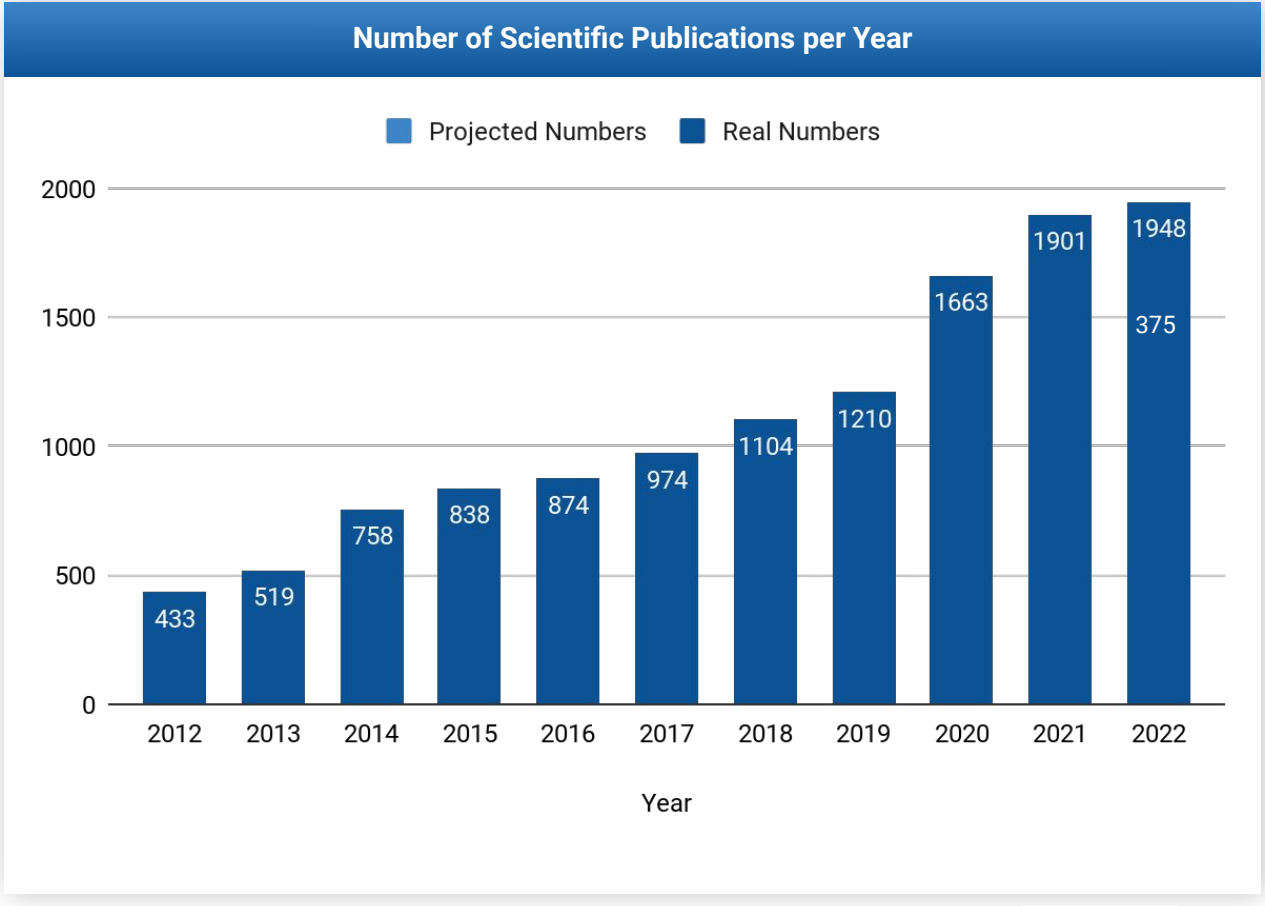


Sources: Subtle Medical

Rise of AI in Radiology: Scientific Publications

Over the recent years, there was an **exponential growth** in the number of papers about AI in radiology, with an increased rate **from 100–150 to 700–800** scientific publications per year during the last decade. In 2022, we predicted to have about **2,020** scientific publications that will involve AI in radiology studies. These data declare a statement that AI becomes **extremely popular** in radiology field.

Represented graph was obtained by calculating the number of scientific articles and reviews in peer-reviewed journals that were published on **PubMed** during the last 10 years. To calculate the projected number of publications in 2022, the regression line was used.



Sources: PubMed, Diagnostic and Interventional Imaging

AI in Nuclear Medicine: Key Business Trends

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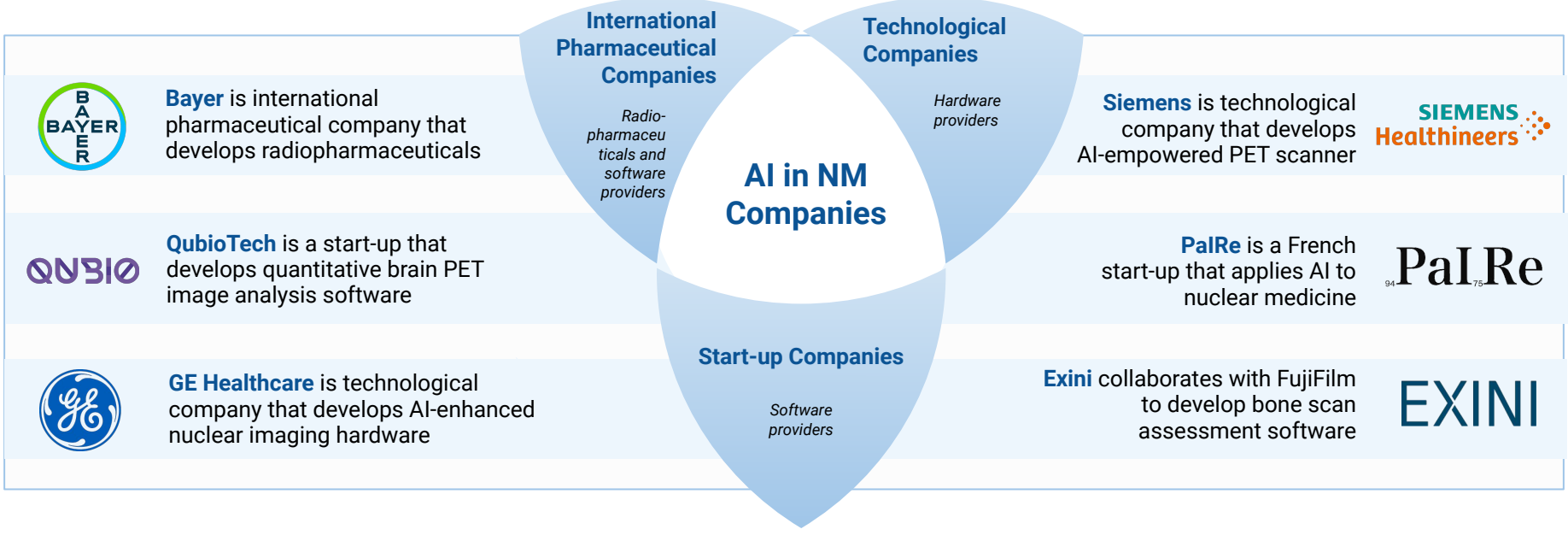
AI Companies in Nuclear Medicine

Companies that develop AI for nuclear medicine can be roughly divided into three categories: **international pharmaceutical companies**, **technological companies**, and **start-up companies**. The global pharmaceutical companies primarily provide radiopharmaceuticals and sometimes software for nuclear image analysis. However, this category is tiny because not many companies develop radiopharmaceuticals, and only a few of them implement AI. Technological companies mainly provide hardware with built-in AI models (such as scanners). Start-ups usually develop software for different stages of nuclear medicine procedure: from planning to clinical decision support.

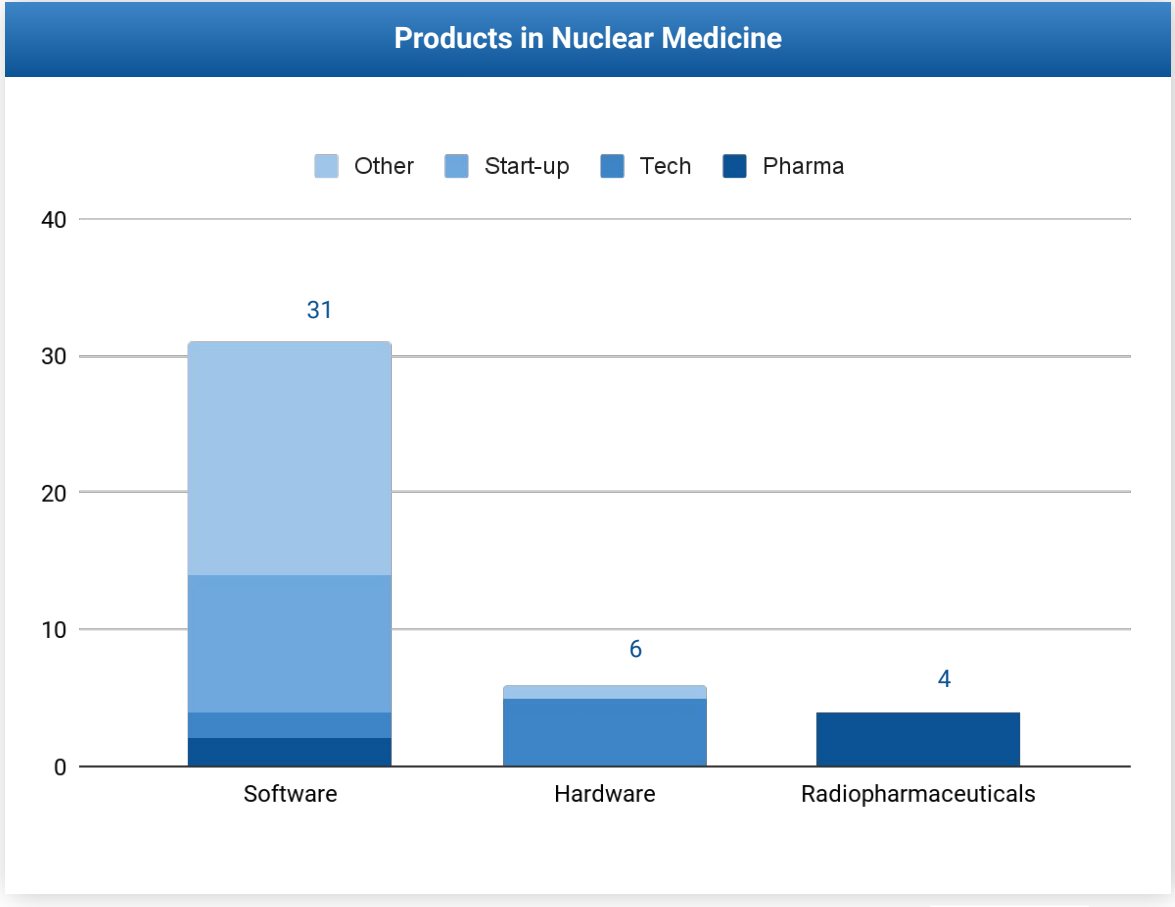


Type of Products in Nuclear Medicine

There are three types of AI products in nuclear medicine: AI-empowered **software** for nuclear medicine procedures, **hardware** with in-built AI systems, and **radiopharmaceuticals** in which AI was implemented at a particular stage.

The broadest category is **software development**: three-quarters of companies are inventing AI-enhanced software for different steps of nuclear medicine procedure: planning, scanning, analysis, and reporting. The software is developed by different types of companies: from international pharmaceutical companies to small start-ups.

The **AI-empowered hardware** is developed mainly by big technological companies, such as Siemens. This category is not extensive because the development of hardware is expensive a requires many professionals with different competence (from AI specialists to engineers and medical specialists).



Start-ups

Software Provides

Hardware Providers

International Pharmaceutical Companies

Clinics & Diagnostic Imaging Centers

Nuclear Medicine in Asia

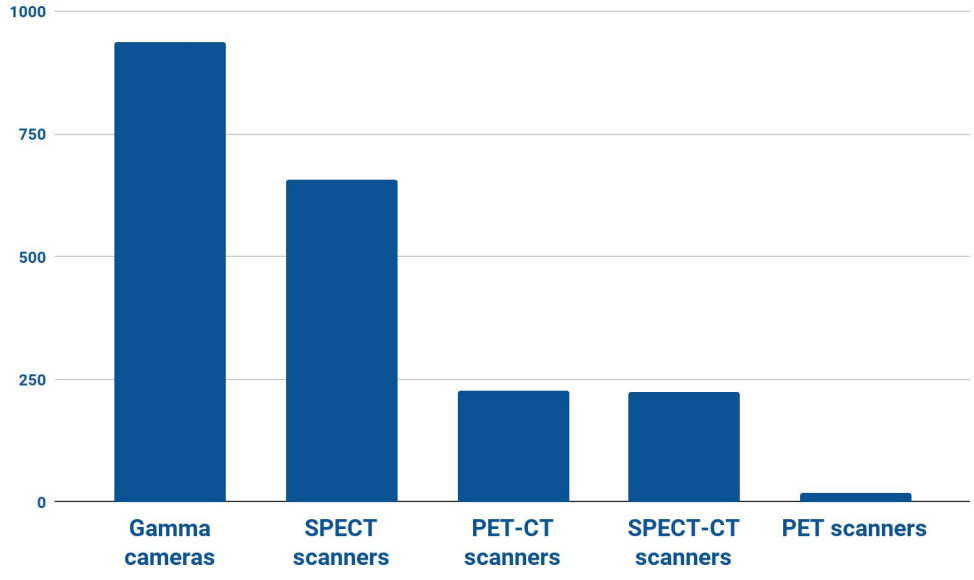
The **nuclear medicine industry** in **Asia** is being driven by the rising incidence of cancer and heart disorders. Nuclear medicine has a lot of promise for treating heart and cancer problems. According to Cancer Index, cancer causes **6,763,000** new cases and **4,499,500** deaths in Asia each year. Cardiology applications will continue to experience substantial market growth.

Due to an increase in the incidence of cardiac patients and clear imaging techniques with the use of diagnostic equipment such as **PET** and **SPECT**, the **diagnostics sector** led the market in 2020 and is likely to continue this trend during the forecast period.

The rising prevalence of cancer, which necessitates early detection for adequate treatment, is predicted to help the **diagnostics segment** gain traction in the Asia-Pacific region.

Furthermore, due to the introduction of radionuclides and radiopharmaceuticals to treat metastatic bone pain, neuroendocrine, and other malignancies, the **therapeutics segment** is predicted to grow at the quickest rate throughout the study period.

Nuclear Medicine Equipment in Asia



Sources: NUMDAB

Asian Governmental Regulations on AI and NM/Radiology

Since 2017, China has continuously introduced medical AI-related policies, and the regulation has been clear and implemented, During last 2 years, the introduction of data security law and personal information protection law has put forwards higher requirements for medical AI enterprises to use patients' personal medical data. The policy is becoming more and more loose to guide the rapid development of China's radiopharma industry.

Country	Classification	Dates	Dept	Law/Regulations	Main Contents
China 	AI and NM/ Radiology (Mainly in AI imaging)	Aug 2021	National People's Congress (NPC)	Personal Information Protection Law	Personal information refers to all kinds of information recorded electronically or in other ways that can identify the personal identity of a natural person alone or in combination with other information, including but not limited to the name, date of birth, ID number, personal biometric information, address, telephone number, etc. For medical institutions and AI enterprises, most of the patients' personal information belongs to sensitive personal information (such as personal biometric information and medical health data). Therefore, when processing these patients' personal information, in addition to the general obligation of personal information protection, we should also strictly comply with the relevant provisions of sensitive personal information.
		Jul 2021	NMPA	Guiding principles for classification and definition of AI medical software	The specific management category shall be comprehensively determined in combination with the expected use of the product, algorithm maturity, and other factors. For the AI medical software with low maturity in medical application (meaning it is not listed or its safety and effectiveness have not been fully verified) if it is used to assist decision-making, such as providing clinical diagnosis and treatment suggestions as lesion feature identification, lesion nature determination, medical guidance, treatment plan formulation, etc., it shall be managed according to class III medical devices; if it is used for nonauxiliary decision-making, such as providing clinical reference information for data processing and measurement, it shall be managed according to class II medical devices.
		Jun 2021	NPC	Data Security Law	Data security law proposes data classification and classification protection system and data security review system.

Asian Governmental Regulations on AI and NM/Radiology

Country	Classification	Dates	Dept	Law/Regulations	Main Contents
China 	AI & NM/ Radiology (Mainly in AI imaging)	Mar 2020	NMPA	Examination and approval of CT image assisted triage and evaluation software for pneumonia (Trial)	In view of the key problems of COVID-19 epidemic, the requirements for ensuring the safety, effectiveness, and controllable quality of products were put forwards according to the principle of 'unified command, early intervention, follow-up review and scientific approval'.
		Nov 2020	National Health Commission	Pilot work plan for Regional Medical Centre Construction	Carry out various forms of medical resource integration pilot, require all three-level public hospitals to participate in and play a leading role, and establish a relatively complete national medical alliance system.
		Jul 2019	NMPA	Deep Learning-aided decision-making medical device software approval points	Provide professional suggestions for the registration and application of corresponding medical device software. The key points include five parts: scope of application, key points of approval, software update, relevant technical considerations, and description of registration and application materials.
		Aug 2018	NMPA	New medical device classification catalogue	Clarify the definition of Artificial Intelligence software as follows: 1) if the diagnostic software provides diagnostic suggestions through its algorithm and if the auxiliary diagnostic function does not directly give diagnostic conclusions, it shall be declared according to the classification of secondary medical devices; 2) if the automatic identification of lesion location needs to provide clearly defined diagnostic recommendations, it must be managed according to the three-level medical device classification to obtain clinical trial certification.
		Feb 2017	National Health Commission	Management specification for AI Aided Diagnosis Technology (2017 Edition)	It specifies the basis for the technical audit of the application for clinical application of AI-assisted diagnosis technology by the technical audit institution, which is the minimum requirement for the medical institution and its doctors to carry out AI-assisted diagnosis technology.

Asian Governmental Regulations on AI and NM/Radiology

Country	Classification	Dates	Dept	Law/Regulations	Main Contents
China 	Radiopharma	May 2022	State Council	Administrative measures for radiopharma	The establishment of a radiopharma production and trading enterprise must meet the conditions specified in the drug administration law, comply with the national regulations and standards on radioisotope safety and protection, perform the examination and approval procedures for environmental impact assessment documents, and obtain a radiopharma production enterprise license or a radiopharma trading enterprise license.
		Jan 2022	NMPA	Circular on further strengthening the administration of radiopharma	The inspection of three consecutive batches of samples of immediately labeled radioactive drugs shall be conducted after obtaining the production license. Drugs containing short half-life radionuclides can leave the factory while being inspected.
		Jun 2021	China Atomic Energy Authority	Medium- and long-term development plan for medical isotopes (2021-2035)	China's first programmatic document on the application of nuclear technology in the field of medical and healthcare points out that by 2025, a number of key core technologies for the development of medical isotopes will have made breakthroughs, and the construction of one-two special production reactors for medical isotopes will be started in time to realise the stable and independent supply of common medical isotopes; by 2035, actively promote the 'going out' of medical isotopes.
		Aug 2019	National People's Congress	Drug Administration Law	A marketing licensor system has been established to separate the marketing license from the production license. The subjects who have obtained the marketing license are responsible for the safety of the whole life cycle of drugs and the production enterprises are responsible for the production process, which has greatly stimulated the vitality of the radioactive drug market.

Asian Governmental Regulations on AI and NM/Radiology

Japan has developed a practical approach to AI-based medical devices, decided on priority areas, created a roadmap for their realisation, and is implementing a 5-year programme under which industry, academia, and government work together to identify and resolve roadblocks to these efforts. The principles for specific measures to promote medical business ventures: 'from regulation to cultivation', 'from caution to speed', and 'from macro to micro'.

Country	Classification	Dates	Dept	Law/Regulations	Main Contents
Japan	AI and NM/ Radiology (Mainly in AI imaging)	Jun 2021	the Cabinet	Regulatory Reform Implementation Plan	Announced policies to further accelerate the development and commercialisation of software as a medical device (SaMD), including AI-based medical devices, in collaborative industry-regulatory development.
		Nov 2021	Ministry of Health, Labour, and Welfare(MHLW)	Drastic Reform of the Review of Advanced Medical Devices	Commonly known as 'DASH for SaMD'. 'DASH for SaMD' is an acronym for 'DX (digital transformation) Action Strategies in Healthcare for SaMD (software as a medical device)' and is designed to promote early commercialisation of new SaMDs by identifying the seeds of SaMDs at an early stage, presenting the concept of review, centralising the consultation service from development to reimbursement price, and establishing a review system and structure based on the unique characteristics of SaMDs. MHLW and PMDA have each established a new department specialising in SaMD to strengthen their systems towards achieving this goal.
		Nov 2019	Senate	Post-Approval Change Management Protocol for Medical Devices (PACMP)	By Amendment of the Pharmaceuticals and Medical Devices Act, PACMP was established as an approval review system for medical devices, including AI-based medical devices. In Japan, PACMP is also commonly known as IDATEN (Improvement Design Within Approval for Timely Evaluation and Notice).
	Radiopharma	2014	Japan Society of Nuclear Medicine (JSNM)	Consensus guidelines for pediatric nuclear medicine in Japan	The dose optimisation in pediatric nuclear medicine research was proposed, and the technical selection of pediatric nuclear medicine was recommended. To establish a radiopharma production enterprise, it is necessary to obtain a radiopharma production enterprise license.

Asian Governmental Regulations on AI and NM/Radiology

Country	Classification	Dates	Dept	Law/Regulations	Main Contents
Japan 	AI and NM/ Radiology (mainly in AI imaging)	Dec 2017	PMDA	Recommendations on Review of AI-Based Medical Devices	The PMDA's Scientific Committee published 'Issues and recommendations on AI-based medical diagnosis systems and medical devices', which aimed to examine the characteristics and risks of AI-based medical devices and points to keep in mind when using them and to help with regulatory review and consultation. (A summary version is also available from Advanced Biomedical Engineering.) These recommendations were prepared by the AI subcommittee of the Scientific Committee and contained the first mention of the concept of AI-based medical device review in Japan.
	Radiopharma	2012	MHLW	Clinical diagnostic guidelines for radiopharma	The guidelines emphasise that the effectiveness of diagnosing radioactive drugs should be demonstrated by the accurate imaging information obtained from the images and the clinical benefits of the information.
India 	AI and NM/ Radiology (mainly in AI imaging)	2016	Ministry of Health and Family Welfare	Electronic Health Records(EHR) Standards 2016	• Data Ownership: Patient's data is stored by the providers. Its owner is the customer without any time restriction. Patients will be able to view these records. • Data Access: Patients will control as to who can access data. Patients will give consent. Patients can correct any record. • Health-Information Disclosure: Data can easily be shared without permission after removing any personal identification. • Access to records by court/government authorities: With the order of the court, the data may be accessed. Besides, for communicable diseases, health information can be disclosed with government's permission. • Encryption of Data: This electronic record of health must be encrypted. Transmission standard is to be strictly followed when transferring such data.

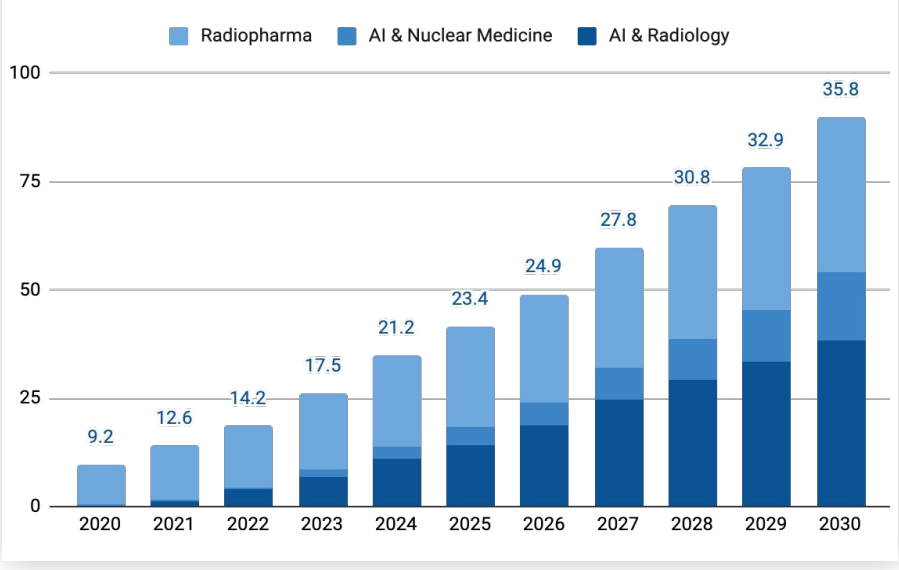
Asian Governmental Regulations on AI and NM/Radiology

The government of India (GOI) has taken a sincere attempt to frame policy in the area of use of AI by the healthcare industry and different effective initiatives to boost up technological innovation in different sectors.
EHR Standards 2016 takes an attempt to regulate privacy standard and data ownership. GOI has emphasised on the need of standardisation of such data. Accordingly, GOI has envisaged standards concerning to information capture, retrieval, storage, analytics, and exchange. It includes clinical code, images, and data.

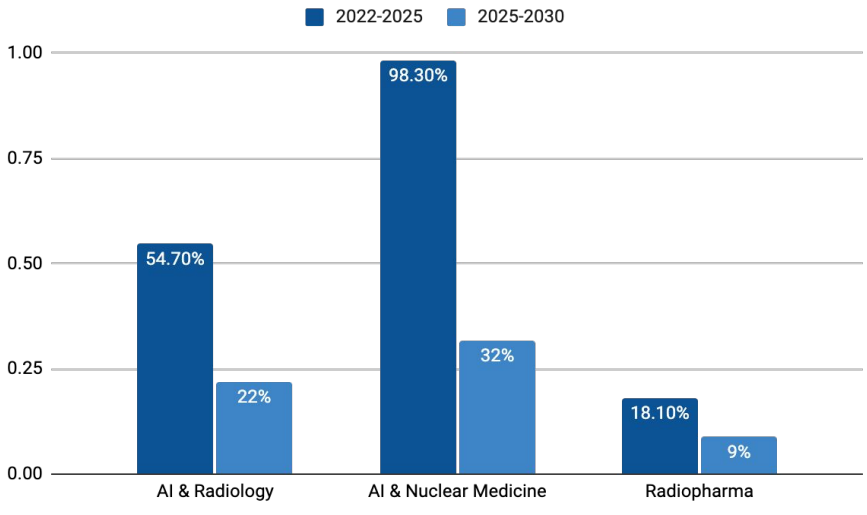
Country	Classification	Dates	Dept	Law/Regulations	Main Contents
India 	AI and NM/ Radiology (mainly in AI imaging)	Mar 2017	Ministry of Science and Technology	The National Data Sharing and Accessibility Policy(NDSAP)	It is being executed by the Ministry of Electronics and Information Technology in the shape of Open Data Platform. Nonsensitive data are generated with the help of government fund. This is open data. It may be shared openly. More data needed to be open to enhance AI potential in healthcare. As such, government should incentivise providers (private healthcare providers) to provide more desensitised data in the open data platform.
		Dec 2016	Ministry of Health and Family Welfare	Electronic Health Records (EHR) Standards 2016	• Responsibility: Healthcare providers have the responsibility to store data ensuring their protection of security and privacy. It is the responsibility of the provider to keep the patient apprised about his/her rights. Also, the patients are to be informed what measures have been taken by the provider to secure the data. • Identification: The identification of the patient will be accepted by the Aadhaar number. If it is not there, two other government ID cards will suffice.
	Radiopharma	In India, the primary regulatory department for radiopharma is the Atomic Energy Regulatory Commission (AERB). AERB participates in on-site inspection, approval of radiation facility license, and authorisation for use of radiopharma. The central drug standards control organisation (CDSCO) is responsible for the marketing license of new radiopharma. BARC is responsible for the supervision and safety monitoring of radiopharma while the radiation and isotope Technical committee (BRIT) is responsible for the R&D, production, and supply of radiopharma nationwide in collaboration with the radiopharma business division under BARC. Among them, BARC provides nuclides from reactor sources to BRIT, which produces various types of radiopharma according to the relevant guidelines of the radiopharma committee.			

AI and NM/Radiology Market Rise in China

AI and NM/Radiology Market Rise in China



CAGR of AI and NM/Radiology Market Rise in China



With the increasing market demand and the acceleration of the regulatory approval of AI NM/Radiology imaging products, the market will enter an exponential growth period, which is expected to grow from less than RMB 10 billion in 2020 to about RMB 89.7 billion in 2030.

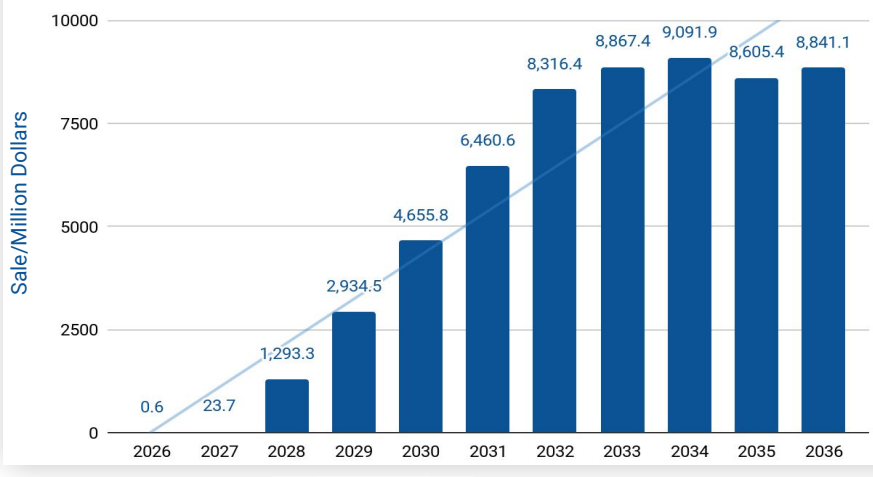
The Radiopharma field will be the most stable growing nuclear medicine market in China.

AI and NM/Radiology Market Rise in China – $^{68}Ga/^{177}Lu$-FAPI

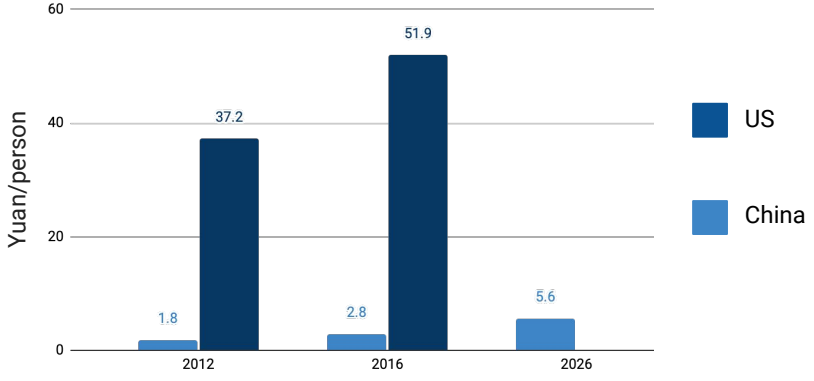
It is estimated that the market share of nuclear medicine treatment will exceed 65% in 2030, and the per capita consumption amount in China has huge development space compared with that in the USA.

$^{68}Ga/^{177}Lu$-FAPI are promising candidates for various solid tumour theranostics, which show potent efficacy and efficiency in investigator initiated trials. In addition, $^{68}Ga/^{177}Lu$-FAPI own the potential to noninvasively diagnose myocardial fibrosis evidenced by 2022 Society of Nuclear Medicine and Molecular Imaging (SNMMI).

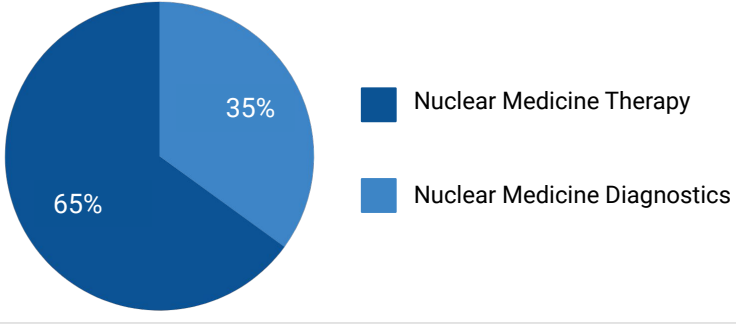
$^{68}Ga/^{177}Lu$-FAPI Sale Predictions in China, $M



China and US Nuclear Medicine Consumption per Person



Global Nuclear Medicine Market Share 2030



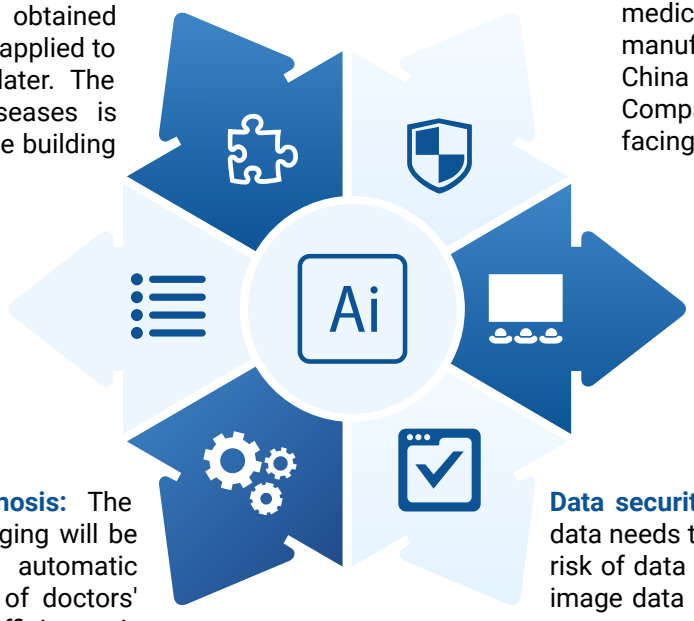
AI and NM/Radiology Market Trends in China

Market Trends

Modularisation of Algorithms: During the construction of AI medical imaging algorithm, the idea of algorithm modularisation is adopted. The modules obtained from the research of a class of diseases are applied to the diseases that need to build models later. The algorithm construction speed of new diseases is improved and the cost is reduced through the building block algorithm.

Intelligentization of equipment: Trace back to the source, intelligentise the device itself, equip the imaging device with AI, accelerate the innovation of medical imaging technology through AI in-depth learning, and make it easier to implement.

Auxiliary diagnosis and automatic diagnosis: The future research direction of AI medical imaging will be towards auxiliary diagnosis or even automatic diagnosis, which will reduce the pressure of doctors' diagnosis and improve its accuracy and efficiency. It has huge space, but it is difficult to land.



Challenges

Policy regulatory challenges: AI medical imaging aided diagnosis software is listed as a class III medical device with high risk in China. No manufacturer has passed the class III Review of China Drug Administration for the time being. Companies that need to pass the registration are facing great regulatory pressure.

Market Sequence Challenge: Maintaining market sequence is the basis for the development of the AI medical imaging industry. At present, there are many 'pseudo AI medical imaging enterprises' on the market. The supervision on this need to be strengthened and clearly defined.

Data security and data quality challenges: Medical image data needs to establish a safe and open mode to reduce the risk of data outflow and illegal use. The amount of medical image data in China is huge, but the quality is uneven. It is necessary to improve the availability of data and meet the training needs of algorithms.

Nuclear Medicine in Europe

Nuclear Medicine Europe (**NME**, formerly **AIPES**) is a European industrial association dedicated to the promotion, education, and protection of nuclear medicine and molecular healthcare in Europe. They work with molecular and radioactive tracers in the realm of **imaging** and **therapy.**

Their goal, in collaboration with **the European Association of Nuclear Medicine** (EANM), is to raise awareness of the role and benefits of **nuclear medicin**e and to continue to collaborate on research into molecular healthcare and its benefits for European residents.

The **EANM's mission** is to provide a forum for the sharing and discussion of recent findings in nuclear medicine, particularly **multimodality imaging** and **related topics.** It promotes and coordinates the exchange of information on the diagnosis, treatment, and prevention of diseases using unsealed radioactive substances and stable nuclide properties in medicine.

The NMEu' position on radiopharmaceuticals are three pillars to drive actions: **patients**, **innovation,** and **healthcare.**

PATIENTS

Full compliance: adoption of all relevant requirements both on radioactivity and pharmaceuticals. Compliance covers the entire process, from R&D to manufacturing, to distribution, to any after sale events.

INNOVATION

Tradition of innovation and commitment to novel, future tracers. Development of new drugs will require a more tailored regulatory approach.

HEALTHCARE

Ensuring products and technology availability for millions of procedures all over Europe.

Sources: Nuclear Medicine Europe, European Association of Nuclear Medicine

Nuclear Medicine in Africa

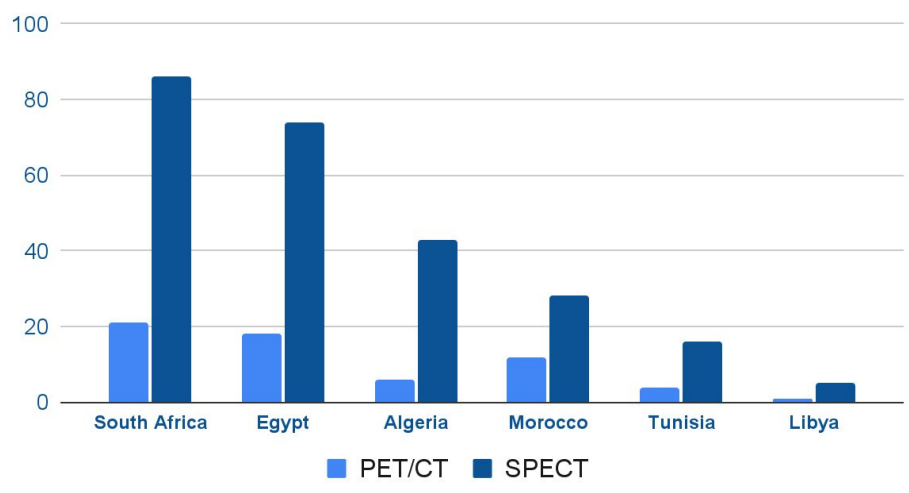
Developing countries face various challenges in the process of nuclear medicine incorporation into the medical sphere. The **lack of nuclear medicine equipment and educated nuclear medicine physicians** are ones of the main challenges for African countries.

On the other hand, the **supply of radiopharmaceuticals** in Africa is very heterogeneous and inconsistent: Among 54 countries, only **South Africa has its own manufacturing and commercialisation pipelines for radioisotopes.** Other countries are dependant mostly on Europe, which makes nuclear medicine even more expensive and less affordable for the low-income countries.

During the last two decades, the nuclear medicine market significantly expanded in Africa; many advances were supported by **International Atomic Energy Agency (IAEA),** promoting coordinated research projects and nuclear medicine awareness.

In the future, **Artificial Intelligence** is likely to be included in the next steps of nuclear medicine development in Africa, making the procedures **personalised, optimised, and safer.**

Nuclear Medicine Equipment in African Countries



The graph above demonstrates the normalised number of PET/CT or SPECT equipment per million of inhabitants of the country. Mentioned countries belong to the upper-middle income class.

In all other African countries not presented on the graph, the number of equipment is in the range of 0-5 per million people.

Sources: Development of nuclear medicine in Africa (Clinical and Translational Imaging, 2022)

Nuclear Medicine in Africa

The existing use cases show that AI is a viable tool for tackling health challenges, reducing costs, and improving health access and quality, which African countries need. But those countries must also enact laws and policies that will guide the application of this technology to healthcare and protect the users.
A number of start-ups have emerged in Africa, concentrated in Egypt, South Africa, Ghana, and other countries.

AI and NM/Radiology background in Africa

1 Billion+
people

39%
Internet penetration

2 Doctors
per 10,000 people

Less than 30%
of hospital facilities get reliable electricity

Huge AI and NM/Radiology Market

AI and NM/Radiology background in Africa

Data Availability and Quality

Low level of digitalisation and electronic medical record use across Africa

Legal and Policy Issues

Some countries in Africa do not have a national digital health policy or strategy

Cost of AI Application

Data acquisition cost

Computing resources cost

System maintenance

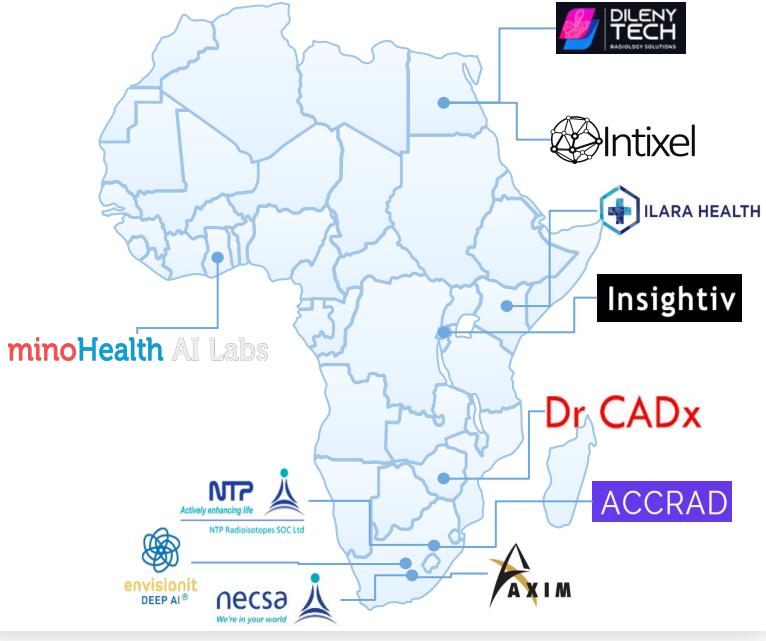
Inadequate Infrastructure

Low Internet penetration

Computing resources cost

Half of Africans have no access to electricity

AI and NM/Radiology Start-Ups in African Countries



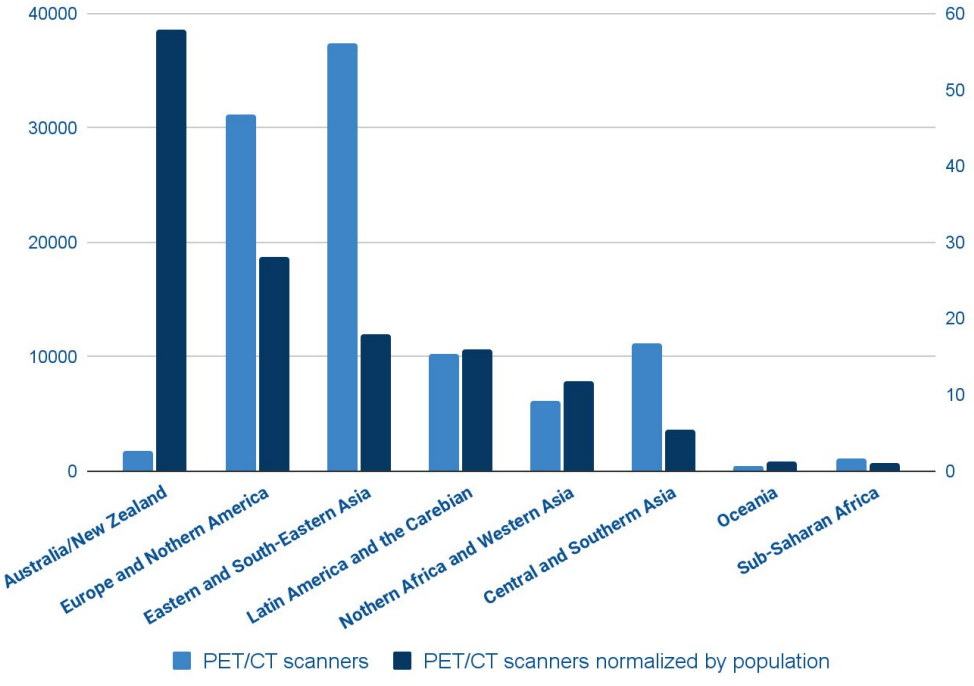
Regional Trends

Increased knowledge of the potential impact of early and prompt diagnosis, as well as the corresponding favourable impact in the management and treatment of chronic illnesses, is one of the key drivers for the nuclear medicine imaging market growth.

Nuclear imaging technology advancements, particularly **PET/PET-CT,** have contributed in the extension of this modality applications beyond **oncology to cardiology**, **neurology**, and **infection detection**. These technical developments have resulted in a significant increase in the number of **PET** and **SPECT treatments**. According to OECD, the number of PET procedures performed in the United States increased in 2020, from **2,200,800** in 2019 to **2,220,300** in 2020.

The expanding usage of PET scanners was responsible for the increased procedure volume. Improvements like the development of **cadmium zinc telluride (CZT)-based detectors**, which allow for simultaneous imaging of physiological and anatomical components, are also likely to promote **SPECT-CT adoption**.

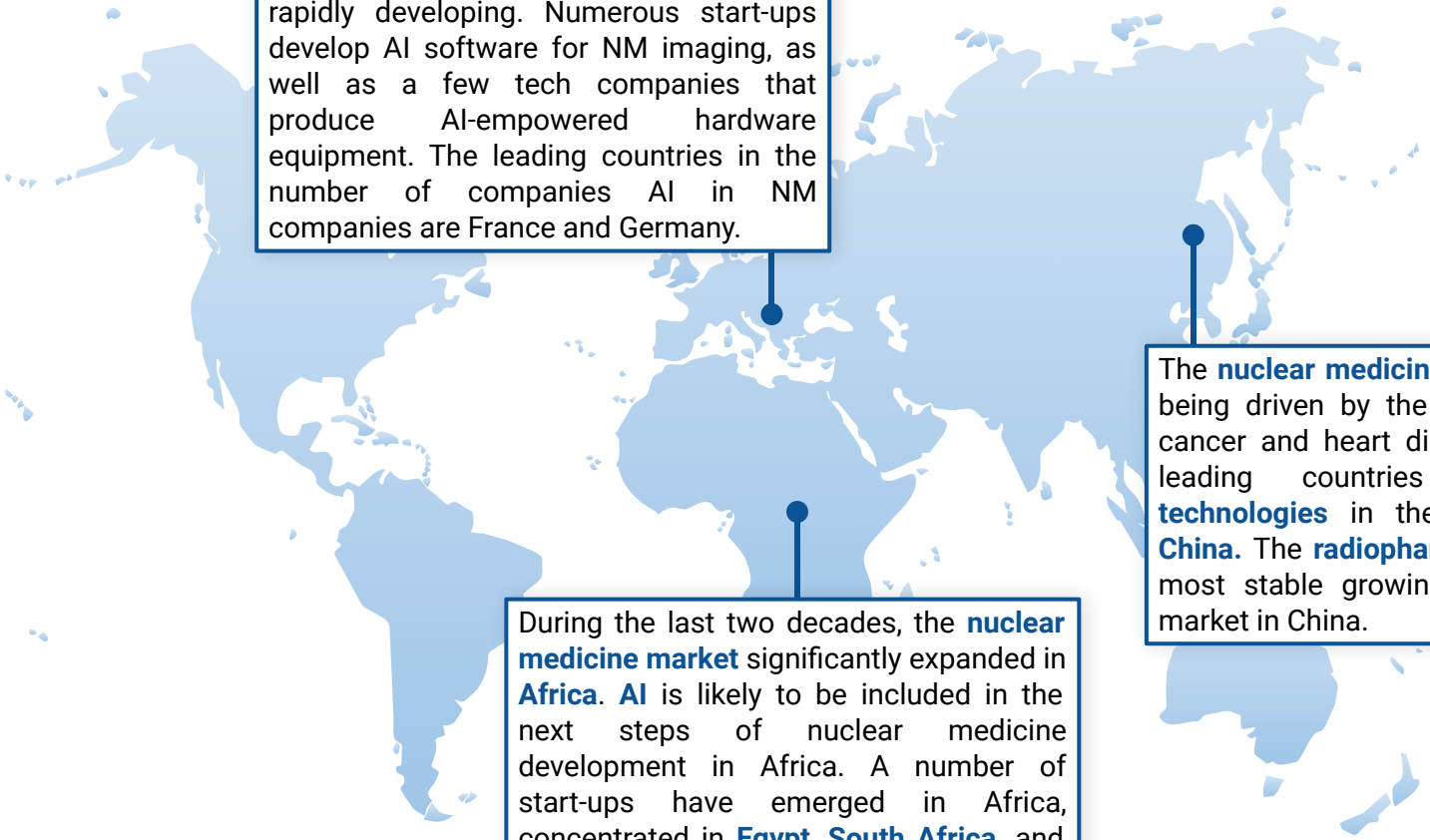
Nuclear Medicine Equipment Worldwide – PET/CT



Sources: Human Health Campus PET/CT

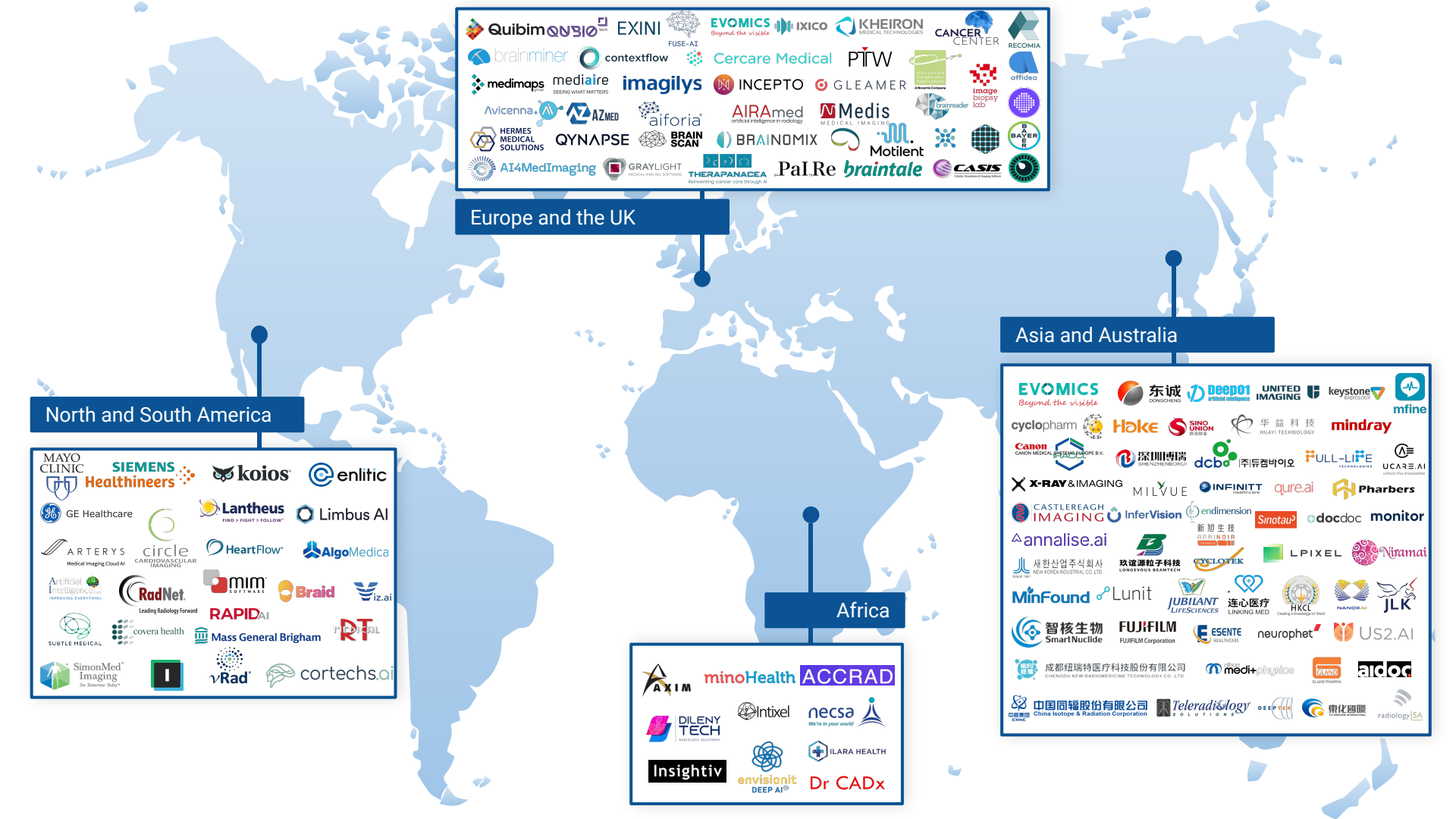
Regional Trends

AI in nuclear medicine (NM) in Europe is rapidly developing. Numerous start-ups develop AI software for NM imaging, as well as a few tech companies that produce AI-empowered hardware equipment. The leading countries in the number of companies AI in NM companies are France and Germany.



The **nuclear medicine industry** in **Asia** is being driven by the rising incidence of cancer and heart disorders. One of the leading countries developing **AI technologies** in the Asian market is **China.** The **radiopharma** field will be the most stable growing nuclear medicine market in China.

During the last two decades, the **nuclear medicine market** significantly expanded in **Africa**. **AI** is likely to be included in the next steps of nuclear medicine development in Africa. A number of start-ups have emerged in Africa, concentrated in **Egypt**, **South Africa,** and **Ghana**.


Europe and the UK
North and South America
Asia and Australia
Africa

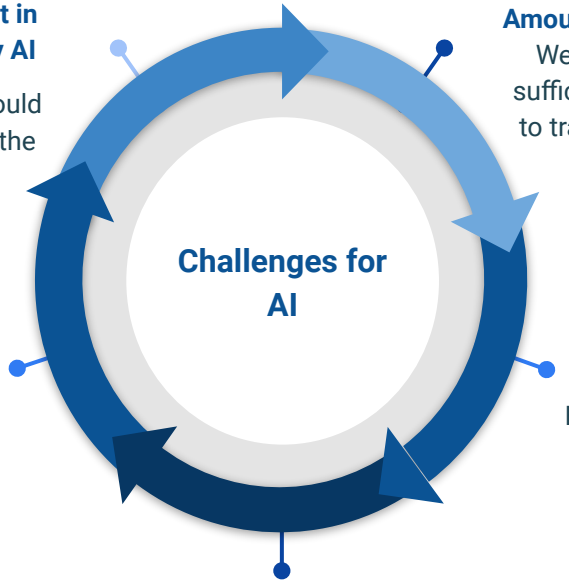
Current Challenges for AI Implementation in Nuclear Medicine

The sky seems to be the limit when it comes to applying **AI in radiology**. At present, however, there are still quite some challenges to overcome before AI will be widely applied and fully adopted in the radiology workflow.

The training of neural networks typically requires **large amounts of data**. The volume available is still several orders of magnitude **behind**. Most successful Deep Learning models are trained on simple 2D pictures, **but are not developed for 3D**. CT and MRI images are usually in 3D, adding an extra dimension to the problem.

Nonstandardised acquisition of medical images creates a challenging situation for the training of Artificial Intelligence algorithms. AI companies need to be very clear on their **performance measurements**. Yet, these metrics **do not always apply**.

However, possibly the biggest challenge AI radiology companies are **facing is the lack of trust in Artificial Intelligence** when it comes to answering questions related to medical image analysis. AI is often seen as a **'black box'** that makes it unclear how exactly it came to its answer.



Sources: Quantib.com

Ethical Issues of AI Implementation in Nuclear Medicine

Perhaps the most contentious topic in AI application to Nuclear Medicine is the **ethical questions** that arise when using human data to develop human-targeted applications. Ethical considerations relate to three distinct areas: **data use, algorithm selection**, and **deployment strategy in clinical and research practice**.

Many AI algorithms operate in a **'black box' environment** where the main steps of analysis are not transparent. The inability to achieve deep understanding in the face of rapidly advancing technology is a big ethical issue. AI faces major ethical issues related to **autonomy, beneficence, fairness, and respect for knowledge.**

An important ethical and social perspective has to do with how AI shapes **human behaviour**. The risk of weakening the social and moral responsibility of people who rely on AI in relation to their fellows has been identified. In addition, this comes with the risk that diagnostic or treatment decision-making, and, therefore, responsibility, could be shifted to autonomous AI systems.

Data used	Algorithm selection	Practice
• Governance	• Regulation	• Cost
• Confidentiality	• Liability	• Availability
• Mitigation of Bias	• Accuracy	• Equity
• Transparency	• Decision making	• Communication
• Relevance	• Acceptability	• Choice
• Privacy		

Sources: Insights into Imaging

Future Perspectives of AI in Nuclear Medicine

Reduced time to diagnosis

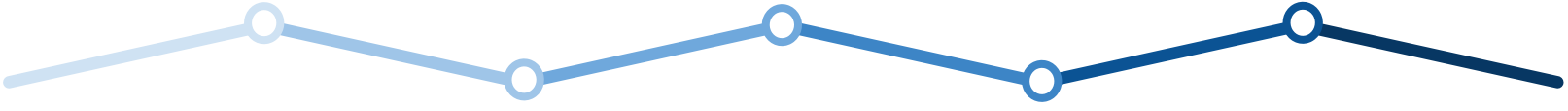
AI can alert radiologists to acute conditions in patients in an efficient and timely manner, accelerating the time it takes to address cases.

From active to proactive detection

AI will empower radiologists to discover additional conditions that were previously undiagnosed or even unknown to the patient.

Impact on the medical profession

Radiologists who use AI will replace those who do not. AI will lead to the decreasing of human resources that is required.



Larger range of tools and better precision

Together with AI, it will become possible to investigate new techniques of image acquisition and tool to analyse them.

Automation of cognitively undemanding tasks

Processes such as image segmentation or finding prior examinations across different PACS repositories will be done by AI.

The number of radiologists has been growing in the double digits for decades, and radiology is predicted to be among the fastest growing fields of the next decade. AI will reshape how radiologists work, shifting their detection of medical conditions from an active to a proactive approach. Understanding these changes can give a better picture of how work will change for radiologists in the near term.

Sources: Hosny *et al* (2018)

Key Takeaways

Nuclear medicine is a field of medicine that uses radioactive substances that are either injected into or ingested by humans to **diagnose** or **treat a disease. For diagnostics**, the patient consumes the radioactive substance, which is then distributed through the human body and concentrated in the disease area. Then the patient is transferred into the scanner, and radioactivity creates an image. **For treatment**, the **radiopharmaceutical** is injected into the patient for therapy, then it concentrates in disease cells and starts to destroy the disease progressively.

There is a difference between radiology and nuclear medicine. **Radiology** refers to generating energy that interacts with the body and produces an image using radiology equipment. Radiology professionals then interpret the image to identify abnormalities and diagnose disease. **Nuclear medicine** refers to the usage of nuclear compounds and radioactive materials and then tracking radiation sources in the body to develop a detailed image or video.

A typical medical imaging workflow can be divided into four steps: **planning and optimisation, scanning and reconstruction, interpretation, and reporting and clinical decision support**. Each step could be improved, accelerated, or completely automated with the help of AI. Most companies that develop AI systems for nuclear medicine applications invent **software for image analysis and interpretation**. This category is the broadest and takes **more than a third of all AI in nuclear medicine companies**.

Key Takeaways

Companies that develop AI for nuclear medicine can be roughly divided into three categories: **international pharmaceutical companies**, **technological companies**, and **start-up companies**. The global pharmaceutical companies primarily provide radiopharmaceuticals and sometimes software for nuclear image analysis. Technological companies mainly provide hardware with built-in AI models (such as scanners). Start-ups usually develop software for different stages of nuclear medicine procedure, from planning to clinical decision support.

Over the years, more and more clinical trials with AI technology appeared for nuclear medicine. The **prominent rise was in 2021** when were started almost three times more clinical trials than in 2020. One of the reasons for this may be the **COVID-19 pandemic** that provoked the active development of AI techniques for medical imaging, and nuclear medicine imaging is not an exception. Additionally, there is a significant growth in the scientific papers: We predict to have about **2,020** scientific publications that will involved AI in radiology studies in 2022.

Increased knowledge of the potential impact of early and prompt diagnosis, as well as the corresponding favourable impact in the management and treatment of chronic illnesses, is one of the key drivers for the nuclear medicine imaging market growth. **AI in nuclear medicine in Europe** is developing rapidly, in particular in the direction of the development of AI software for NM imaging and AI-empowered hardware equipment.The **nuclear medicine industry** in **Asia** is being driven by the rising incidence of cancer and heart disorders.

Report Authors

DEEP PHARMA INTELLIGENCE

THE YUAN

EVOMICS
Beyond the visible

Report Authors

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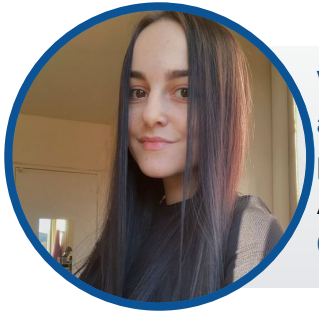

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Overview of Proprietary Analytics by Deep Pharma Intelligence

DEEP PHARMA INTELLIGENCE

THE YUAN

EVOMICS
Beyond the visible

Deep Pharma Intelligence — New Era in Pharma Analytics

Deep Pharma Intelligence (DPI), an analytical subsidiary of Deep Knowledge Group, is a highly specialised think tank in the area of BioTech innovation profiling, market intelligence, and BioTech development advisory. The company is dedicated to producing powerful data mining and visualisation systems, interactive analytics tools, and industry reports, offering deep technical insights, market intelligence, and strategic guidance in the high growth and significant opportunity areas.

DPI is Focusing on Three Key Activities:

Conducting Market Intelligence

Producing regular **open-access** and **proprietary reports** on the emerging topics and trends in the pharmaceutical and healthcare industries. All reports are supported by our back-end analytics systems and tools that deliver fresh insights and updates about opportunities and risks.

Creating Big Data Analytical Dashboards

Building a comprehensive **Big Data Analytical Dashboard** (SaaS) as a one-stop-platform for all market and business intelligence operations our customers may need, including profiling thousands of companies, market signals and trends based on tens of millions of constantly updated data points.

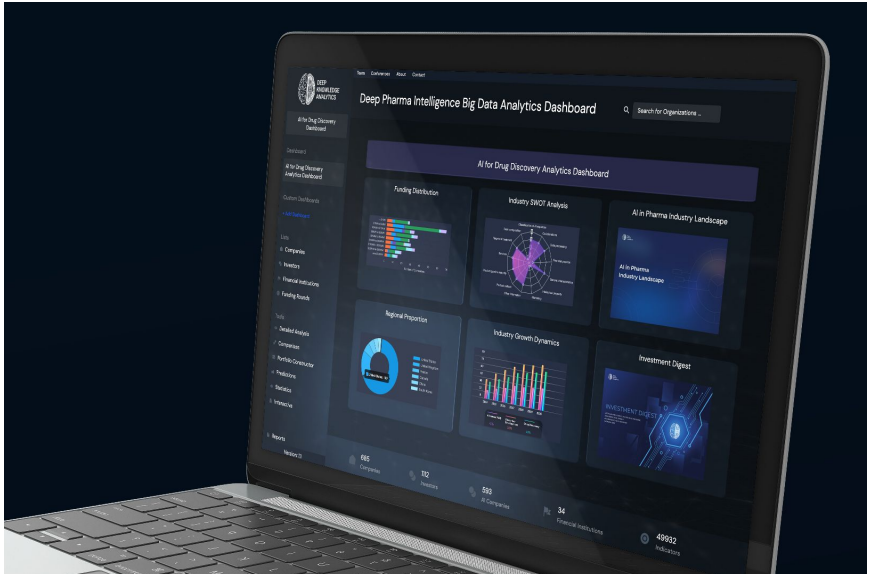
Producing Scientific Content

DPI provides a **full-cycle development of articles, scientific journals, and books**. We are ready to develop a detailed Requirement Specifications document, including layout of the journal, fully designed branded book, with example templates for each chapter.

AI in Drug Discovery Analytical Dashboard

AI in Drug Discovery Analytical Dashboard is a fundamental tool for strategic insights, opportunity evaluation, competitor profiling, and other purposes relevant to pharma and BioTech decision-makers, life science investors, consulting companies, and regulatory agencies.

600	Companies
1,100	Investors
290	R&D Collaborations
120	Clinical Trials
170	Parameters of Automated SWOT Analysis



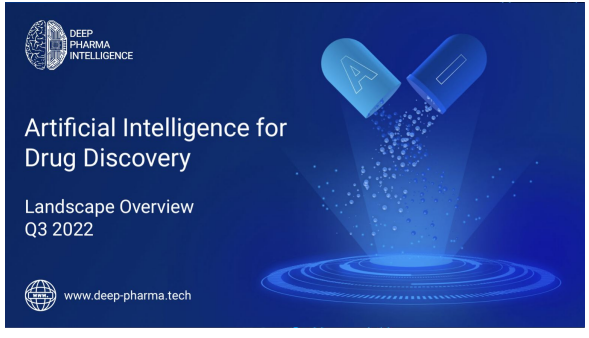
Market Intelligence Focus

Automated SWOT Analysis	Stock Price Forecasting	Interactive Chart Builder
Automated Competitive Analysis	Financial Portfolio Constructor	Matching Tool for Investors

Comprehensive Market Intelligence

Deep Pharma Intelligence's proprietary services include **custom consulting projects based on the specific customer needs,** as well as a collection of preproduced 'ready-to-use' proprietary reports, developed by our research team and covering general trends and specific action ideas and strategy insights related to the most promising business prospects (e.g. new technologies, BioTech start-ups), M&A prospects (e.g. pipeline development targets), and strategic growth ideas (trends profiling, industry overviews, etc.).

Selected Open Access Reports



Artificial Intelligence for Drug Discovery Landscape Overview, Q3 2022 is an analytical report that aims to provide a comprehensive overview of the AI in drug discovery industry, clinical research, and other aspects of pharmaceutical R&D.

Epigenetic Drugs Q2 2022 report aims to provide a comprehensive overview of the current state of the epigenetic drugs market and research. The aim of this report is to provide insights into the diversity of possible epigenetic targets, mechanisms of their action in treating cancer and other diseases.

Landscape of Advanced Technology Companies in Pharmaceutical Industry Q4 2021 is an analytical report providing insights into the expansion of technology developers and vendors in the pharmaceutical space, as well as their increasing role in the pharmaceutical business.

Business Consulting Services

Deep Pharma Intelligence offers a comprehensive range of **consulting services**, including **market and competitor research, technology scouting and due diligence, investment landscape profiling, and comprehensive analytics support for investment decision-making.**

Investment Landscape Profiling

Identifying investment trends in the pharma, BioTech, medicine, healthcare, drug development technological space, investments risk profiling based on risk tolerance, risk capacity, and risk requirements.

Technology Scouting and Due Diligence

Identifying, locating, and evaluating existing or developing technologies, products, services, and emerging trends. The service includes business, science and technology, intellectual property (IP) profiling, and potential assessment.

Market Research

Thorough market assessment within a specific industry in the field of pharma, BioTech, medicine, healthcare, drug development, AI, and others.

Competitor Research

Competitive analysis of companies, technologies, technological sectors, etc. Competitive analysis includes SWOT analysis and competitive profiling.

Link to the Report: www.deep-pharma.tech/ai-in-nuclear-medicine

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